DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

APRIL 1959

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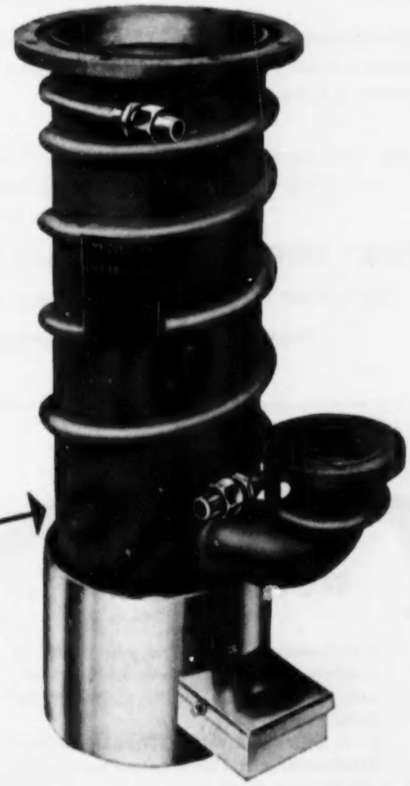

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Photograph of part of the Geothermal Power Station at Wairakei, New Zealand. (See p. 140)

THE PROGRESS OF SCIENCE

SCIENCE, EDUCATION AND SOCIETY

It is a welcome feature of contemporary heart-searching about the position of science in Britain that there is general acceptance of the Estimates of the Advisory Council for Scientific Policy, that by 1970 our annual output of scientists and technologists will have to be doubled as compared with 1956. Yet compelling though this assertion is, there is danger that very acceptance will concentrate attention on the actual statistical progress being made towards reaching it, while insufficient thought may be given to the educational system as such, and especially to questions of quality and balance. Indeed, there is much force in Sir Eric Ashby's cogent observation:*

> "A century or more ago the scientist was as much an individual as a poet is. . . . There is now a risk that he may become simply a unit of scientific manpower. I do not deny that for certain very narrow purposes it is convenient to do sums in which scientists and technologists are considered as so many units of scientific or technical manpower. The danger is that people who habitually do such arithmetic come to think of scientists and technologists as nothing but manpower units and places which produce them as assembly lines of manpower production."

In truth, problems of quality and quantity go together and are very often inextricably inter-related. For example, the shortage of science and mathematics teachers is the greatest single educational problem facing this country. In plain statistical terms: a net annual increase of at least 1400 in the total number of science and mathematics teachers is required compared, despite special measures taken, with a figure of less than 1000 per annum which is being realised. While this shortage is inseparable from the general shortage of teachers, and of the measures, especially regarding pay and status, which must be taken to resolve it, the problem has a special aspect. Science teachers are scarce, good science teachers are even scarcer, for teaching is an art: in the final analysis, whatever your qualifications, you can either do it, or you can't. Recent surveys have spotlighted the low percentages of grammar school candidates in the Ordinary Level GCE examination actually emerging with passes in both "science and mathematics". This may in part reflect other factors, such as the calibre of the candidates themselves or the poor quality of school laboratories, but one may legitimately express some concern about the state of science teaching. How much, we wonder, is dreary and half-hearted, when it could be questioning, lively, and exciting?

To improve the quality of science teaching, may it not be necessary to enlarge the pool from which science teachers are recruited?—a task which it may be too late to tackle at the university stage but which involves consideration of tendencies towards premature specialisation by schoolchildren in either science or the humanities. Indeed, it is often argued that Britain gets her education "on the cheap", that we have an admirable élite education in the sense of securing the final product, the university graduate, faster than in any other comparable country, but that this is achieved at the high price of the loss of slower-developing talent, particularly for the sciences. The Economic Commission for Europe, in reporting on technical manpower, commented in May 1957:

> "The problem of premature specialisation seems to be particularly acute in the U.K., where the first decision as to educational career has normally already to be made at the age of 11 years, when children are separated into grammar, technical, and secondary modern schools."

Of course, the problem has yet further ramifications, especially the balance between literary and scientific subjects in the curriculum of secondary, not least the public, schools, and there unquestionably is ample scope for more pupils to take science and mathematics papers in both the Ordinary and Advanced Level of the GCE examination.

Admittedly, the problem of the syllabus is especially complex. Reformers must come to terms with what the High Master of Manchester Grammar School has described as "the law of the conservation of the curriculum—for everything you put into the curriculum you must take something out". There is one matter, however, which to scientists does need highlighting—the teaching of Russian, the world's second scientific language. Though many reasons may be advanced by way of explanation, the fact remains that for pupils taking "A" Level languages in the GCE in 1957, 6495 took Latin, and a mere 62 Russian.

Basically, of course, problems in scientific education reflect social attitudes as well as pedagogic theory. No country is probably as dependent on part-time study through evening classes by those in industry in its programme, nor through its day-release and sandwich course system so potentially vulnerable to a change in economic mood. There is the further problem—not easy to solve in a free society—of persuading those who have traditionally sought an academic type of education to take up technical work. Above all, there is the task at the universities of convincing advocates of the liberal studies that science is itself a humanity and scientists that their subject, too, needs a humanistic approach. How is this intellectual curtain to be drawn aside? Not, we venture to suggest, by sticking "a few bits of science on the outside of the fabric", nor, *mutatis mutandis*, a few bits of the humanities, but rather, to return to Sir Eric Ashby's dissertation, by recognising that "the path to culture shall be through a man's specialism, not by by-passing it", and that modern technology which concerns the application of science to the needs of man and society could become the cement between science and humanism.

Important though the content of education is, one issue is of vital urgency for the whole of mankind—The Internationalisation of Space, and of Space Research. Scientific and political leaders of all nations must now create the International Space Research Institute, and they must formulate a Law of Space; COSPAR must become executive and not merely advisory. This issue is vital for the future of all mankind. *Caelum Commune!*

* "Technology and the Academics: An Essay on Universities and the Scientific Revolution." Macmillan, 1958.

NEW ZEALAND'S GEOTHERMAL POWER STATION IN OPERATION

The world's second geothermal power station was brought into operation in November 1958, when electric power from the geothermal station at Wairakei, in the centre of the North Island of New Zealand was switched into the national grid.

Power from underground reservoirs of natural steam was pioneered at Larderello, in Italy, and reports on the Italian scheme assisted New Zealand engineers in exploiting the enormous power resources of the North Island's thermal area.

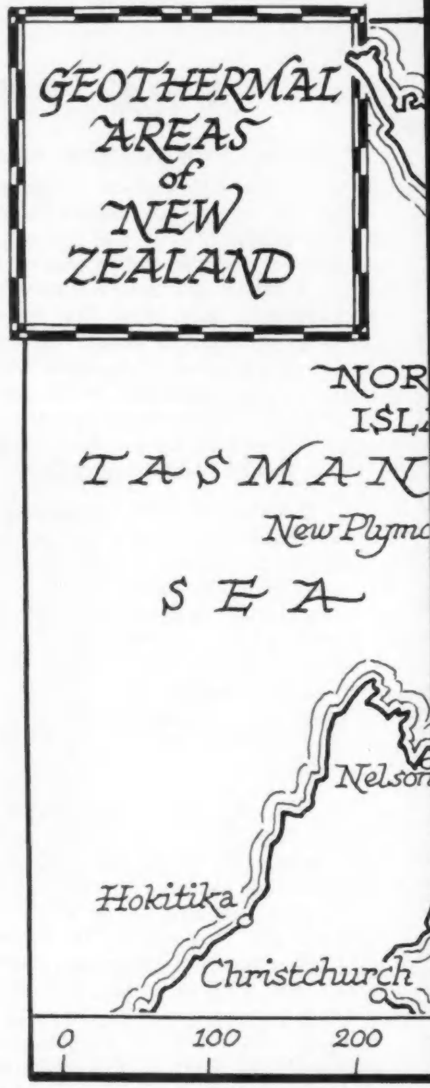
The Wairakei scheme is at present generating only 1500 kW, but as further bores are linked to the turbo-alternator this will be increased to 6500 kW.

The first stage of the £21 million project will produce 69,000 kW, using twenty-seven bores reaching as much as 3000 ft. underground. Further plant is being installed to bring the station up to a second-stage output of 151,400 kW. It was announced in February 1959 that a contract for electric generators, worth £2 million, had been awarded to a British firm to complete the second stage.

Completion of the third stage, however, will bring generation to 252,600 kW of the cheapest power in the world.

Test boring at Wairakei began less than eight years ago, and now this tourist area is a maze of pipes, engineering equipment, and steam bores which can be seen and heard for miles.

Steam-vents, mud pools, and geysers along the volcanic belt of the North Island have shown for a long time that there is high-pressure steam below the earth's crust, and scientists have long been interested in its power potential. Proposals for its use in industry were made twenty years ago. George Bernard Shaw was greatly impressed by the North Island's thermal area when he visited New Zealand in the 1930s and suggested using the underground steam for industrial purposes.



An aerial view of the Wairakei geothermal project. Wairakei Hotel can be seen in the centre of the photograph.

In 1949 the New Zealand Government, heeding a warning by the State Hydroelectric Department that hydroelectricity would soon be insufficient for the North Island, directed a geothermal investigation.

The first bores were drilled in 1950, near the Wairakei Hotel. Success was immediate. Tremendously powerful jets of steam rushed up the bores with a harsh roar that could be heard for many miles, and white clouds billowed back into the bush, covering trees with a fall of pumice dust.

Today there are more than fifty bores between 500 and 3000 ft. deep, roaring into the atmosphere the equivalent of 90,000 kW. It was essential for those working on the site that the deafening noise be reduced; so conical steel silencers, later replaced by a series of increasing dimensions, were attached to the bore outlets. A water and steam separator has since been developed.

Pressures at the well-head vary between 70 and 200 lb./sq. in. when steam is discharged, and bores of up to 8 in. in diameter are used. The new power station must be assured of a long-lasting supply of steam—enough for at least twenty years. Tests have shown some changes in the quantity and quality of steam in some of the bores, but it seems that the power sources are dependable.

There have been technical difficulties during the development of the project. Steam to drive generators must be dry, for too much water condensing on the turbine blades would cause damage. Steam must also be free from impurities which might clog delicate machinery. As the steam coming from bores contains quite a lot of water, special equipment has had to be designed to dry the steam.

The power station has been built on the bank of the Waikato River, about half a mile from the Wairakei Hotel. Steam is fed to it through 20-in. insulated steel pipes which run mostly above the ground, but which pass underneath roads. Contracts were let for the supply of 8 miles of main and side pipelines. About forty firms undertook contracts

Preparations for the blowing of a geothermal bore are extensive and thorough before the actual releasing of the steam takes place. A steel collar is fitted round the pipe, four stout strainers are fitted to bolts set in concrete. In the background another bore pours steam across the valley.

for the project. The consulting engineers are the British firm of Merz and McLellan.

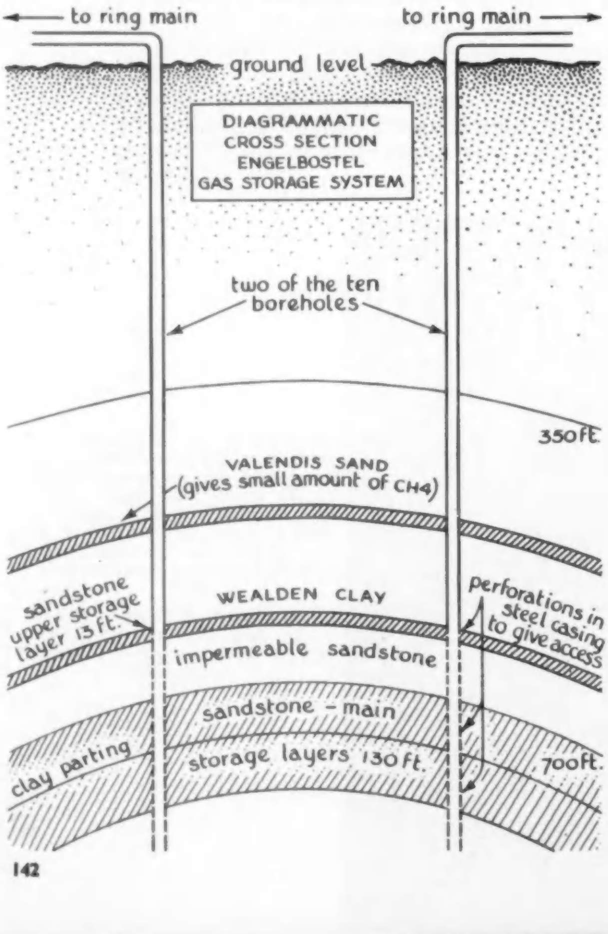
The power potential from shallow drilling at Wairakei and other areas in the thermal zone has been estimated on the basis of the present heat flow. Three areas in the Rotorua district, some 60 miles north of Wairakei (Waimangu, Whakarewarewa, and Ohinemutu) are excluded. Waimangu is considered unsafe because there have been volcanic eruptions there in the past. Ohinemutu and Whakarewarewa are almost part of the town of Rotorua. After Wairakei, the chief areas of potential power are Waiotapu and Orakeikarako, also not far from Rotorua. Another is at Te Teko, where a pulp- and paper-mill is already using the thermal resources. (Te Teko is some 40 miles north-east of Rotorua.)

The natural heat-flow from fourteen centres has been estimated at 7390 million BThU an hour, or a minimum electric power potential of 250,000 kW. As it is unlikely that areas yielding the equivalent of less than 10,000 kW will be put into production, the total can be reduced to about 200,000 kW. This figure is based on heat-flow measurements at the surface, and it seems that at least this amount will be obtained on drilling. Almost half of the originally estimated heat-flow for the whole of the thermal area is already discharging from the Wairakei bores.

How much more can be tapped is not known, but it is thought that the estimate of 250,000 kW is a safe conservative minimum.

Even if this figure is the limit, it will be an immense help towards easing the North Island's power situation, for 250,000 geothermal kW will produce almost one-and-a-half times as many units as the same amount of hydroelectric generating capacity. This is because the hydrostations on the Waikato River (a chain of ten will soon be completed) are designed for a load factor of between 50% and 60%, while the geothermal station will operate on a load factor of up to 90%.

New Zealand's thermal area is a vast triangle stretching across the central North Island. It contains almost every known form of thermal activity and attracts tourists from many parts of the world. The apices of the triangle are a sporadically active volcano (Mount Ruapehu) in the south, a small spa town (Te Aroha) in the west, and a blazing island (the seldom visited White Island) roaring miles offshore in the Bay of Plenty, in the east.



UNDERGROUND STORAGE OF GAS

Gas-holders form a familiar (and not always welcome) item in the landscape of most civilised countries. Although they seem bulky, the capacity of a group of the ordinary water-sealed type is likely to be less than the volume of gas produced daily by a gas-works. While, therefore, they are invaluable as a means of spreading the load evenly over the day, they do nothing to help the problem of equalising the rate of production in winter and summer.

The latest method for storing gas is to force it into suitable geological strata underground rather than building expensive containers on the surface. This at first sounds a rather wild and dangerous proposal, but in fact it has been standard practice in the U.S.A. for years. There, they are able to use exhausted gas-fields for the purpose. This is an advantage because, as the strata have contained gas before, they must therefore be gas-tight.

In Europe the last few years have seen the development of three underground storage sites, mostly used for manufactured gas (coal gas), rather than for natural gas (or methane). The pioneer installation was at Engelbostel, a small village to the north of Hanover. Exploration for oil at this point before the war had shown the presence of some thick layers of waterlogged sandstone lying in a shallow dome-formation below thick beds of impermeable clay. In 1952 the German pipe-line company, Ruhrgas A.G., began work on the site, and by the end of 1957, 110 million cu. m. of towns' gas was stored in the geological strata 750 ft. below ground.

One can more easily realise the meaning of these figures if one appreciates that the volume of gas is about 4000 million cu. ft. and that the largest gas-works in Britain only produces about 150 million cu. ft. per day. A very large surface gas-holder contains about 7 million cu. ft. of gas when full. This underground reservoir is so big that it can be filled during the summer and partially emptied during the winter. In an emergency (such as the very cold spell which occurred in February 1956) it can supply half the country with gas for a few days. In normal working it enables gas production to be maintained at a uniform rate throughout the year; and this represents considerable economy in operation.

The sandstone into which the gas is forced is a firm, greyish rock having a porosity of about 30%. As the gas goes in, salt water is forced out of the pores, and is displaced sideways and downwards. This is a rather slow

process, and the technique of establishing an underground reservoir consists of driving out the water so that there is room for the gas. Once this has been done, the amount of gas held by the reservoir depends largely on the extent to which it is compressed. A ring of bore-holes round the "dome" is connected up by a distribution pipe, and gas is either compressed into the ground or withdrawn from it, according to the demands of the moment.

Another even larger underground reservoir has been established near Versailles; here the winter supplies for Paris can be accumulated during the summer. Hamburg put a smaller scheme into operation last winter; in this case it will be refinery gases (mostly methane) which will be stored for use as required. In Britain an experimental project is in hand in County Durham; this will probably come into operation some time this year.

FRANCESCO TORTI (1658–1741)

That great killing disease of mankind, malaria, has finally been conquered, but the victory was not easily won, for its victims must be reckoned in millions, and its malign influence can be deciphered on many a page of the story of civilisation. Centuries had to elapse before the problem of its origin was solved, while its prevention is largely recent history. For long the nature of the malady was obscured by the perpetuation of fallacious beliefs dating back to antiquity, with the result that treatment remained empirical and ineffective. It was a memorable day in the annals of medicine when travellers to the New World returned with supplies of cinchona. Rightly did Ramazzini say in 1702: "Surely after the use of this remedy has become known . . . it must be avowed that, concerning the doctrine of fevers and the method of curing them, a change has been made comparable to that which all know followed, in military affairs, the invention of gunpowder."

As so often happens with a new remedy, cinchona was thought to be a "wonder drug" and administered indiscriminately to sufferers from fevers of all sorts, thus tending to bring the medicament into disrepute. The man who established that cinchona was, indeed, a "wonder drug" and a specific remedy for certain fevers was born at Modena in Italy just over 300 years ago, on November 30, 1658.

Francesco Torti first studied law, sustaining his thesis in philosophy in 1675. He then turned to medicine and graduated M.D. at Bologna in 1678. At the early age of 23 he was appointed second professor of medicine at Modena. The university, which had been restored by Francis II, Duke of Modena, had for its senior professor Bernardino Ramazzini, a pioneer in occupational diseases. In his youth Torti had composed a number of popular oratorios, but he now devoted all his time and talent to the practice of medicine. Many of his patients suffered from febrile diseases, which he had ample opportunity to study in their different clinical aspects. A diligent and keen observer, he correlated the symptoms of the intermittent fevers and demonstrated conclusively that cinchona bark was specific for these, but not for other fevers. He was also the first to describe "pernicious malaria". Laying down the proper dosage necessary to cure the various types of malaria, he made clear the importance of continued treatment to prevent relapse. His exhaustive clinical study on the action of

Specially drawn for DISCOVERY by Frank Horrabin.

the drug ran into many editions and was recognised in England by his election as corresponding member of the Royal Society. The first edition, "Synopsis therapeutices specialis", was published in 1709. Subsequent editions (1712, 1730, 1732, 1743, 1756) bore the title "Therapeutice specialis ad febres periodicas perniciosas inopinato ac repente lethales, una vero china peculiari methodo ministrata sanabiles".

Torti's reputation was such that he received tempting offers of chairs both at Torino and at Padua, but he preferred to work in the city of his birth. When he was aged about 73, a paralytic stroke left him with a tremor of his right hand, which made it difficult for him to feel a patient's pulse or to carry out other examinations. He retired to the country, where he spent much of his time hunting. While attending church one day, he had a second stroke, which rendered him voiceless and paralysed down the right side of the body. Prescribing for himself, he made a partial recovery, and during his last years found solace in poetry. He died on February 15, 1741, aged 83.

Torti has been credited with being the first to use the word "malaria" (from the Italian for "bad air"). Harry Wain, in his recent book, "The Story behind the Word" (1958), states that Torti in 1718 published a classic treatise on the various climatological fevers in which the term "malaria" is used for the first time. None of his works, however, bears that date, and several eminent scholars, such as P. R. Russell, have carefully searched the 1712 edition of "Therapeutice specialis" without finding the word "malaria". It appears that the first to use the term in a medical text was Francesco Jacquier in 1743.

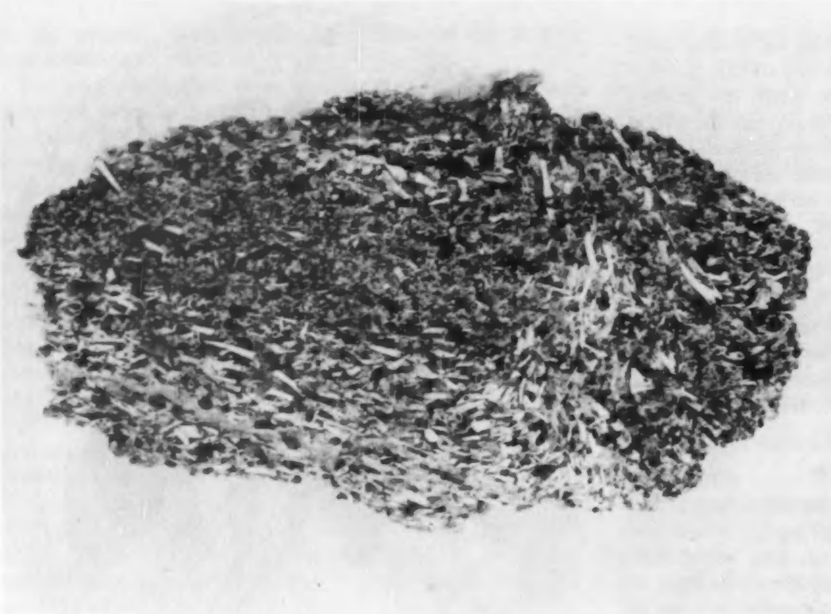


FIG. 1. Unprepared block of matrix from Pant Quarry. All the white objects are bone. The bones have been orientated along the direction of the stream which swept them into the fissure.

THE FIRST MAMMALS

K. A. KERMACK
AND
FRANCES MUSSETT
University College, London

We are all interested in our ancestors: in the origin of our own family and, by an extension of this, in the origin of the human race. Similarly the problem of the origin of the mammals is one of the most intriguing in palaeontology.

DEFINITION OF A MAMMAL

Mammals have a number of attributes which separate them from the other classes of tetrapods (four-footed animals)—the amphibia, reptiles, and birds. These characters are:

(1) the young are nourished by milk produced by the mother;
(2) the body is generally covered by hair (this is true even of ourselves though much of our hair is very short and fine);
(3) the main artery from the heart is on the left side;
(4) the lower jaw consists of a single bone—the dentary. In the other tetrapods the lower jaw is compound consisting of a dentary and a number of other bones, usually five.
(5) the jaw hinge is formed by a convex surface at the back end of the dentary, the condyle, which articulates with a concave facet on a skull bone (squamosal). The jaw hinge in the other tetrapods is between a facet on one of the lower jaw bones (articular), and a condyle on a skull bone (quadrate).
(6) there is a chain of three small bones (malleus, incus, and stapes) which transmits sound from the ear-drum to the inner ear. The other tetrapods have only one such bone, the stapes.

Since fossils consist simply of "hard parts" it is only the last three characters that can be used in studying the origin of the mammals.

GEOLOGY AND FIELDWORK

The geological time-scale is divided into a number of eras (Fig. 2). The last era is the Cenozoic, which started some 60 million years ago and is sometimes popularly known as the "Age of Mammals". From this time on we have an abundance of fossil mammals to study, and the evolution of mammals such as horses, cats, and elephants has been worked out in great detail. But these forms do not help us to see the origin of the mammals: at the beginning of the Cenozoic they are already too advanced for that.

The preceding era is the Mesozoic, and this is often called the "Age of Reptiles" as it was then that the great dinosaurs and strange sea-beasts, the ichthyosaurs and plesiosaurs, flourished. The Mesozoic era lasted from about 200 to 60 million years ago. During this time much of what is now southern England was laid down. One of these deposits, the Stonesfield Slate, near Oxford, yielded, in 1764, the lower jaw of what was until recently one of the earliest known mammals. Despite the early date of this discovery, subsequent finds only served to show how extremely scarce Mesozoic mammals are. This may be due partly to their very small size, which ranges from that of a mouse to that of a cat. With rare, and rather unimportant exceptions, such discoveries came from just three localities: the original one at Stonesfield, of Middle Jurassic age (about 140 million years ago), and two of extreme Upper Jurassic age (about 120 million years ago). One of these is in the Purbeckian of Swanage in this country and the other in the Morrison at Como Bluff, in the State of Wyoming, U.S.A. All three localities yielded little but isolated teeth and jaws. Thus although the history of the mammals stretched back for 140 million years, for the most important part of this history they were known by fragmentary and tantalising remains.

In the past few years, however, exciting new finds have been made, both in this country and in the U.S.A. In 1947 Dr W. G. Kühne visited Glamorgan, South Wales, looking for Mesozoic tetrapods in the fissures of the Carboniferous Limestone. At the end of the Triassic period this limestone formed an island rising from a considerable expanse of water which periodically may have dried up. In this limestone the rain formed caves and underground watercourses just as it does on a similar land-surface today, for example, in parts of Derbyshire, Somerset, and Yorkshire. In these fissures the bones of small land animals were trapped, buried, and hence fossilised.

In the Mendips, where conditions were similar during that period of the Mesozoic, Dr Kühne had already discovered fissures containing the bones of small reptiles. Later he continued his work in the Vale of Glamorgan. It was crowned with success: he made a most important discovery. In a quarry to the west of Cardiff he found a few small pieces of rock. This material had once formed part of one of these fissures, although the fissure itself had been quarried away. From this he was able to extract some teeth which proved later to have come from one of these early mammals. These he named *Morganucodon watsoni*. Since the age of this fissure was Rhaetic (top of the Trias, about 160 million years ago) these teeth were much older than the Stonesfield mammals. Teeth of a similar age had been found previously in Holwell, Somerset, and also in Canton Schaffhausen, Switzerland. The important thing about Kühne's discovery was, however, that the teeth came from fissure deposits. Hence there was a greater possibility of finding more complete remains of the animal. Teeth, by themselves, are not really sufficient to show whether the animal was a mammal or not; at least the back end of the jaw is needed so as to see whether the mammalian condyle on the dentary is present. Indeed, until skull bones were found some isolated reptile teeth were classified as those of mammals. Kühne found no more, and in 1951 returned home to Germany. Then, together with Mrs Kermack, we carried on the search for fossils in Glamorgan. In 1955 we were rewarded by an extremely important and rich find at Pant Quarry (Figs. 1, 3, and 4). Here the bones of many thousands of individuals of a tiny mammal, about the size of a shrew, were found in a small fissure at the top of the quarry. They are similar to or identical with *Morganucodon*. Now we had not only isolated teeth but bones of the whole skeleton. Although they are broken and waterworn, this was the first time that abundant material, and material comprising more than simply teeth and jaws, had been found of any Mesozoic mammal. The matrix from Pant, so far prepared, has yielded more specimens than all the previous discoveries anywhere in the world put together. That the Pant mammal should be found in such

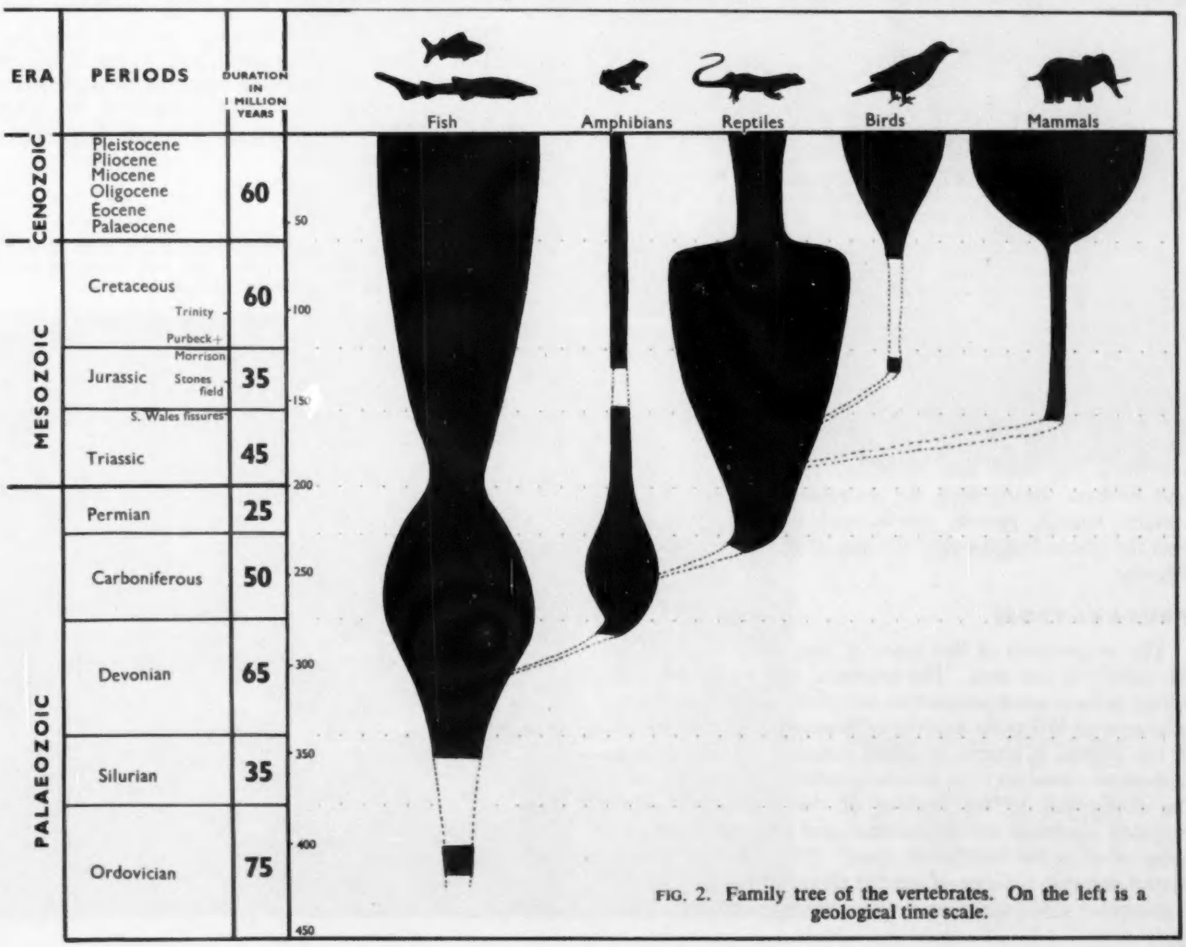


FIG. 2. Family tree of the vertebrates. On the left is a geological time scale.

FIG. 3. The fissure at Pant Quarry from which much of the mammal material came. The bone-bearing matrix is the clay which can be seen in bottom right corner of the photograph. Some more is being dug out by the two workers at the farther end of the fissure. The fluting shown on the limestone wall behind the fissure is due to the action of the water which brought in the bones.

quantity is truly remarkable. We were able to collect several hundredweights of valuable material. Later finds have been made at other quarries in the area. In these the bone has been less abundant but much less worn and broken. Along with the mammal, the fissures have yielded lizards, insects, snails, and plants. The snails and the plants suggest that the age of the fissure filling is Rhaetic.

PREPARATION

The preparation of this mass of very small bones from the matrix is not easy. The matrix is marly clay (that is, a clay with a good proportion of calcium carbonate) containing a considerable amount of haematite, an iron oxide. If the matrix is placed in dilute formic acid the calcium carbonate dissolves, the matrix gradually breaks up and the bones fall to the bottom of the container. After repeated washings, to remove the acid and the finer particles of clay, the residue is dried. The material is then passed through a series of graded sieves and sorted under a binocular microscope at a magnification of ×30. This is a very laborious and time-consuming job. Finally, the bones are preserved by being dipped in a solution of plastic lacquer before being stored in small glass tubes. Some of the larger and more complete specimens are prepared mechanically with a fine needle and a binocular microscope. This takes much longer than the acid process but there is no risk of the bone falling into small pieces.

The teeth and jaws are the easiest bones to recognise. This is fortunate: Mesozoic mammals have to be classified on their teeth because, until now, almost nothing but teeth were known. The Welsh mammal teeth show that the fissures contain representatives from two of the five major groups of Mesozoic mammals (Fig. 10).

DENTITION

By far the commonest mammals found in the fissures are members of the Docodonta, which includes *Morganucodon*. The total number of teeth in their jaws was not larger than in a modern mammal, such as an opossum, which has a comparatively primitive dentition. It has often been thought that ancestral mammals would have had a much larger number of teeth than either present-day mammals or Late Jurassic mammals. We now know that this need not be so (Figs. 5, 6, and 7). On each side of the upper and lower jaw there were five incisors in front, followed by a large canine. Behind this came the cheek teeth. In the upper jaw there were two premolariform teeth followed by four molariform teeth, and in the lower jaw two or three premolariform teeth were followed by five or four molariform teeth. The total number of the lower cheek teeth seems to have been always seven. According to

FIG. 4 (*below*). Some of the bones *in situ* in the clay. On the left is a docodont lower jaw, and above it, in the centre, the lower jaw of a lizard.

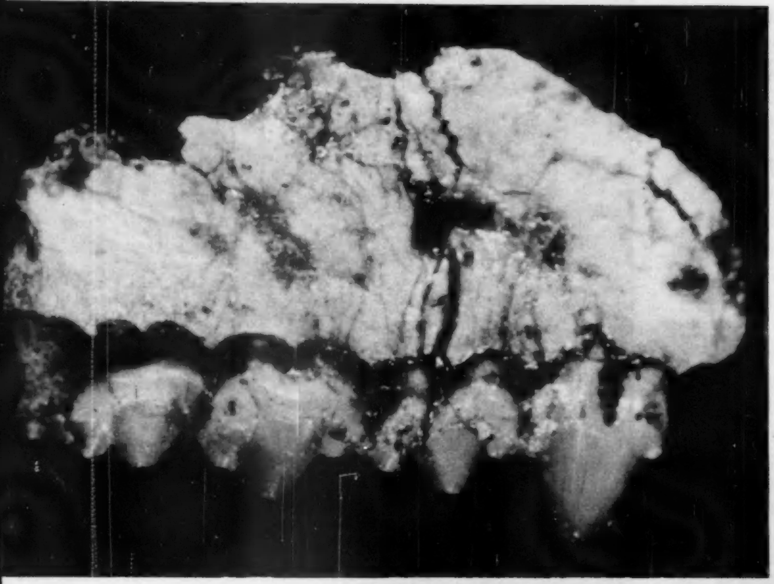


FIG. 5 (*left*). Maxilla of docodont from Pontalun Quarry, in external view, to show the cheek teeth. Note the way in which the first tooth on the right (second premolar) differs in shape from the four molariform teeth to the left of it. The first premolar is missing. Total length, 5·2 mm.; length of tooth row, 4·5 mm.

FIG. 6 (*right*). Maxilla of docodont from Ewenny Quarry, in external view, showing the full number of cheek teeth (six). The crown of the first molar is broken off. Length of tooth row, 6·5 mm.

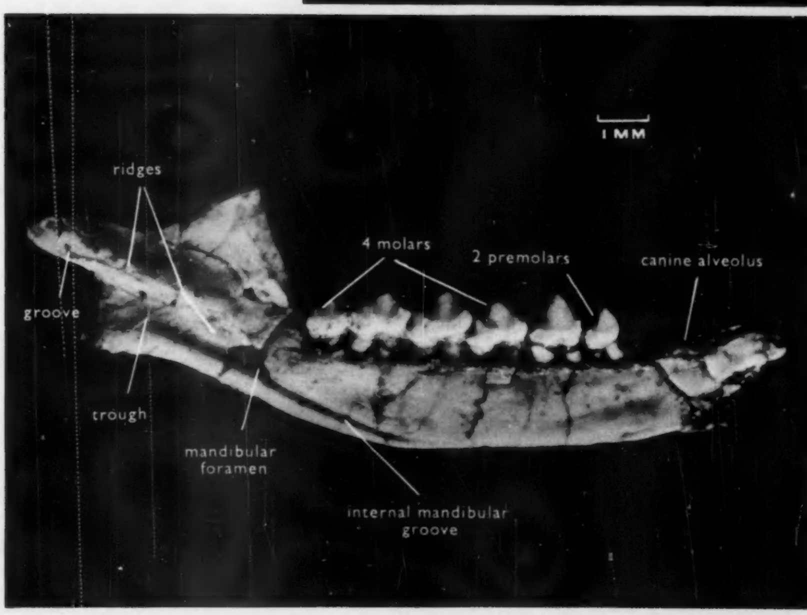


FIG. 7 (*left*). Internal view of lower jaw of docodont from Pontalun Quarry. Note the ridge and trough structure at the back end of the jaw. Four molars and two premolars can be seen, the first premolar being absent. Total length, 15 mm.; length of tooth row, 6·3 mm.

the normal convention the dental formula* can therefore be written thus:

$$2\times\frac{5:1:\ 2\ :\ 4}{5:1:2/3:5/4}=50.$$

At one time it was thought that the cheek teeth of ancestral mammals would form a graded series, becoming increasingly complex on passing from the front of the jaw backwards. This theory has also been disproved by our material as each type of tooth is quite distinct and there are no intermediates.

In one respect the dentition of the Welsh docodonts is more primitive than that of other mammals. As in some of the advanced mammal-like reptiles, the posterior incisor in the upper jaw is borne by the maxilla. Such maxillary incisors are unknown in other mammals, in which all the incisors are implanted in the premaxilla.

PRIMITIVE FEATURES

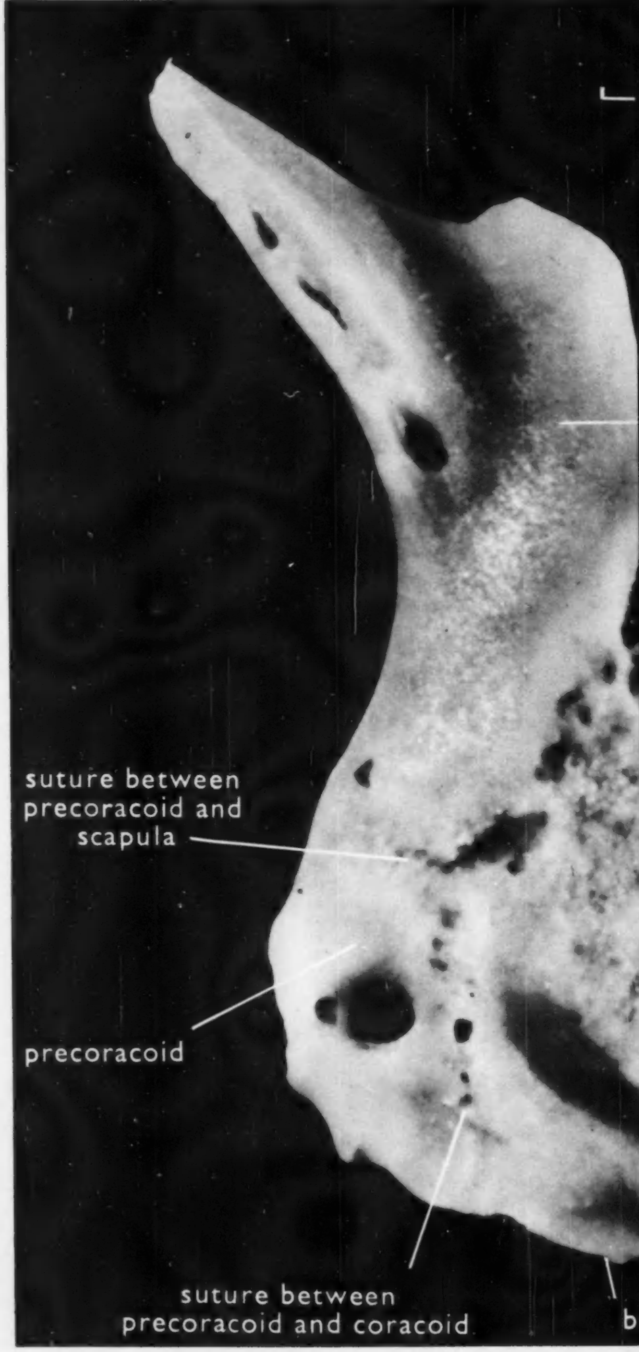
Apart from the skull the skeleton is very primitive, as might be expected. For example, in all living mammals except the egg-laying monotremes, the duck-billed platypus (*Ornithorhynchus*), and the spiny ant-eater (*Echidna*), the shoulder-girdle consists of at most only two pairs of bones, the dorsal scapula, or shoulder-blade, and the ventral clavicle, or collar bone. In *Ornithorhynchus* and *Echidna*, on the other hand, the shoulder-girdle consists of no less than four pairs of bones plus a median unpaired bone, the inter-clavicle, which joins the ends of the two clavicles below. The other extra bones are the paired coracoids and precoracoids, which also lie below the scapula. In *Ornithorhynchus* and *Echidna*, the precoracoid does not reach the scapula. In the South Wales docodonts the shoulder-girdle (Fig. 8) consists of the same bones as in the monotremes, but here the precoracoid does reach the scapula, just as it is known to do in the reptiles from which the mammals evolved. It is, in fact, the most primitive mammalian shoulder-girdle known.

THE DOCODONTA AND MONOTREMATA

But the shoulder-girdle is not the only point of resemblance between the Welsh mammals and the monotremes. In the latter the mandibular branch of the fifth nerve to the lower jaw leaves the skull through a hole in the bone which surrounds the inner ear (the petrosal bone). In every other mammal this nerve passes through another bone, the alisphenoid, which lies in front of the petrosal. The condition found in the monotremes is a specialisation which was formerly thought to be peculiar to themselves. It now seems likely that the docodonts had a similar arrangement of the petrosal bone and that the mandibular nerve of the lower jaw passed through it. The character has no obvious adaptive value and it seems unlikely that the two different groups would have evolved it independently. It probably indicates a real affinity and suggests that the monotremes evolved from animals something like the docodonts.

* The dental formula enumerates the different types of teeth on one side only; the upper teeth being above the line, lower teeth below it. Man has 2 incisors, 1 canine, 2 premolars, and 3 molars in each half of the upper and lower jaws, and this can be expressed as either

$$2\times\frac{2:1:2:3}{2:1:2:3}=32 \qquad \text{or} \qquad I\frac{2}{2}:C\frac{1}{1}:P\frac{2}{2}:M\frac{3}{3}$$



DOUBLE JAW ARTICULATION

The most remarkable feature of the Welsh docodont skeleton lies in the structure of the back end of the lower jaw. The posterior end of the dentary bore a well-developed condyle which formed the typical mammalian jaw hinge with the squamosal bone in the skull. Fig. 7 shows a wide trough, lying at the back of the jaw, bounded above by a prominent ridge which passed back to the condyle. Such a trough and ridge structure is known in advanced mammal-like reptiles, where it houses some of the other bones which go to make up the reptilian lower jaw. (It will be remembered that in reptiles the lower jaw

is usually composed of six bones, while in mammals the lower jaw consists of a single bone, the dentary.) The trough and ridge structure in the docodonts must have had a similar function and hence have housed accessory bones of the lower jaw. That this was its function is shown by one unique specimen from Pant Quarry, in which one of the reptilian accessory bones can actually be recognised.

Thus in the Welsh docodonts we have a mammalian type of articulation together with the compound lower jaw characteristic of reptiles. We probably have, in fact, even more. Running back to the condyle and lying beneath the ridge is a groove. This groove must have been for the reception of a bone and the only bone that could have lodged in it is the articular, as in mammal-like reptiles. This is the bone which in all reptiles forms the lower part of the jaw hinge. If this surmise is correct we have in these docodonts the new mammalian and the old reptilian jaw hinges working side by side. The docodonts are as good a transition between the Class Reptilia and the Class Mammalia as is *Archaeopteryx* between birds and reptiles and are the perfect "missing link".

SYMMETRODONTS

The other kind of mammal found in the Welsh fissure deposits is a symmetrodont. Symmetrodonts have a simple type of molar tooth (Fig. 10), consisting of three cusps arranged in a triangle, and probably form the basal stock from which the modern higher mammals (marsupials and placentals) arose. They are our earliest mammalian ancestors.

The symmetrodonts are much rarer in the Welsh deposits than the docodonts and they are known mainly from isolated teeth. We have, however, a few fragments of lower jaw (Fig. 9). These show a trough and ridge structure like that of the docodonts and this suggests that these early symmetrodonts also had a compound lower jaw. Whether

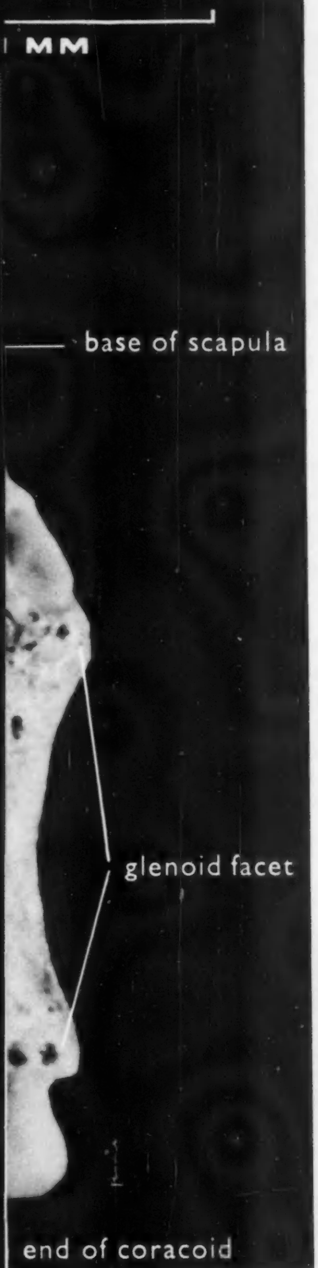


FIG. 8 (*left*). Pectoral girdle of Welsh docodont. Note that although the precoracoid has been excluded from the glenoid facet it still retains the sutural contact with the scapula which is lost in the monotremes. Total length, 4·1 mm.

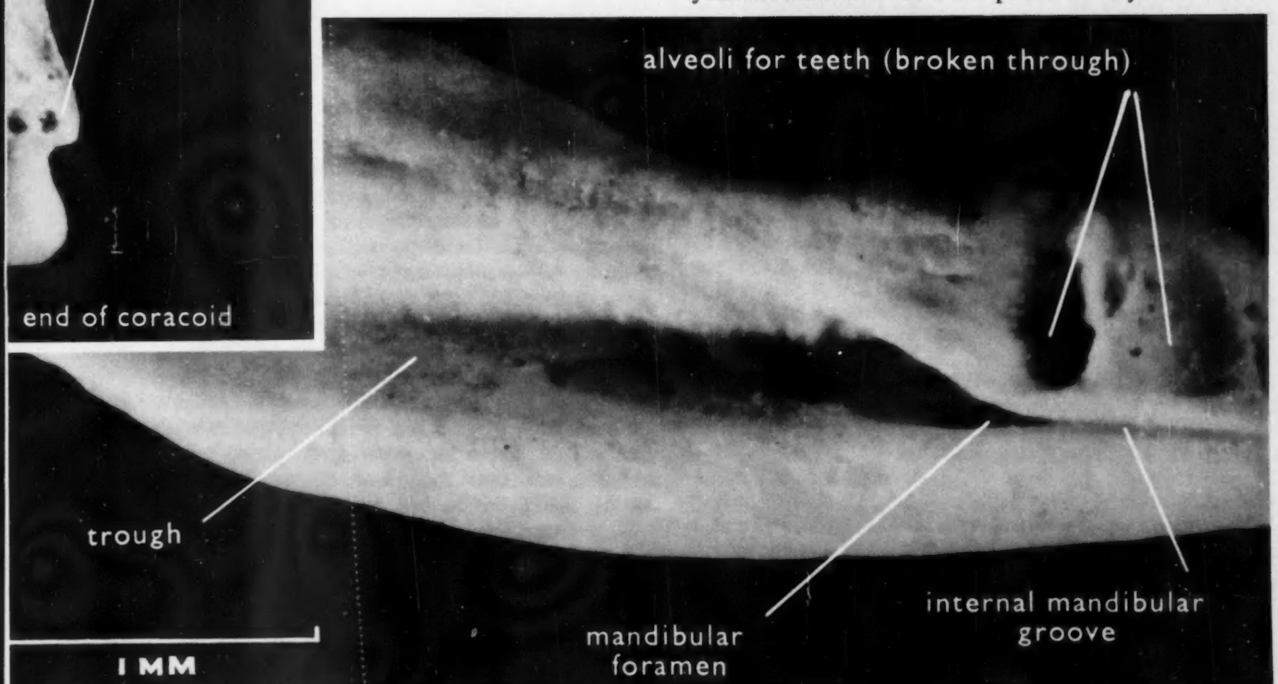


FIG. 9 (*below*). Part of the lower jaw of a Welsh symmetrodont. Note the deep trough running backwards from the mandibular foramen and compare it with the trough shown in the docodont (Fig. 7). Total length, 4·4 mm.

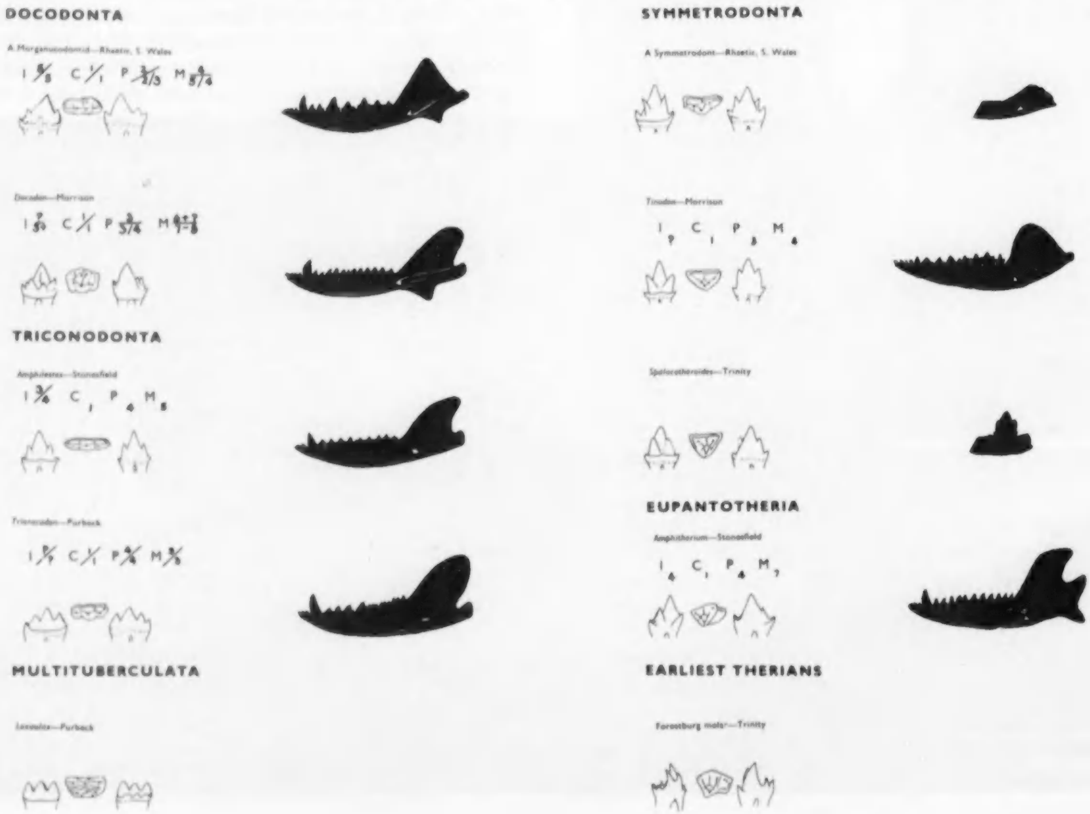
or not they had a double jaw articulation is less certain as the material is so fragmentary, but from the size of the trough it seems probable that they did.

As far as the structure of the lower jaw is concerned the docodonts show no evolution during their recorded history: the last docodonts, those from the Upper Jurassic of England and the U.S.A. having the same kind of jaw as their forerunner from the Upper Trias of South Wales.

The Upper Jurassic symmetrodonts, on the other hand, show considerable evolutionary advance on their Upper Triassic ancestors. The ridge and trough structure had vanished and there is no possibility of a double-jaw articulation; only the mammalian squamosal-dentary articulation is left. Only one of the reptilian jawbones (the splenial) found in the Welsh mammal may still be present. In the last few years important finds have been made, in the Trinity from the Middle Cretaceous of Texas, by Prof. Patterson. A jaw fragment of these most recent symmetrodonts shows that the lower jaw has become typically mammalian and consists of the dentary alone (Fig. 10).

On the structure of the teeth, by themselves, we should have no hesitation in classifying all known symmetrodonts in a single order. One of the most surprising results to come from the study of the early mammals is to find that such great and fundamental changes could take place in the structure of the lower jaw and of the jaw articulation without being reflected in any way in the structure of the teeth.

FIG. 10. Diagrams of the lower molars and dentaries of some Mesozoic mammals. The teeth are seen in lingual, crown, and buccal views; the dentaries in internal view.



THE RELATIONSHIPS OF EARLY MAMMALS

As the docodonts and the symmetrodonts both had this mixture of fundamental reptilian and mammalian characters, and yet are strikingly different in other ways, they must have separated from each other at a very early stage in their evolution—so early in fact that their common ancestor must still have been a reptile.

From the Docodonta probably came the present-day monotremes, and from the Symmetrodonta the other pantotheres plus the modern placentals and marsupials (Fig. 11).

The affinities of the other two orders of primitive mammals of Jurassic age, the triconodonts and multituberculates, are more doubtful.

The Tricondonta had become established as a separate order of mammals before all the accessory jawbones had been lost. Thus they may have arisen from the reptiles independent of the other mammals. Alternatively, the triconodonts may be an early offshoot of the symmetrodont-therian stock, or they may be related to the docodonts. At the moment there is not enough evidence to enable us to decide which of the three theories is correct.

The multituberculates are a very isolated order, showing no affinities to any other mammals. They, too, probably arose independently from the reptiles.

Finally, Crompton has recently described a small animal from South Africa which he has named *Diarthrognathus broomi*. This shows, according to him, a primitive form of double-jaw articulation. *Diarthrognathus* appears to

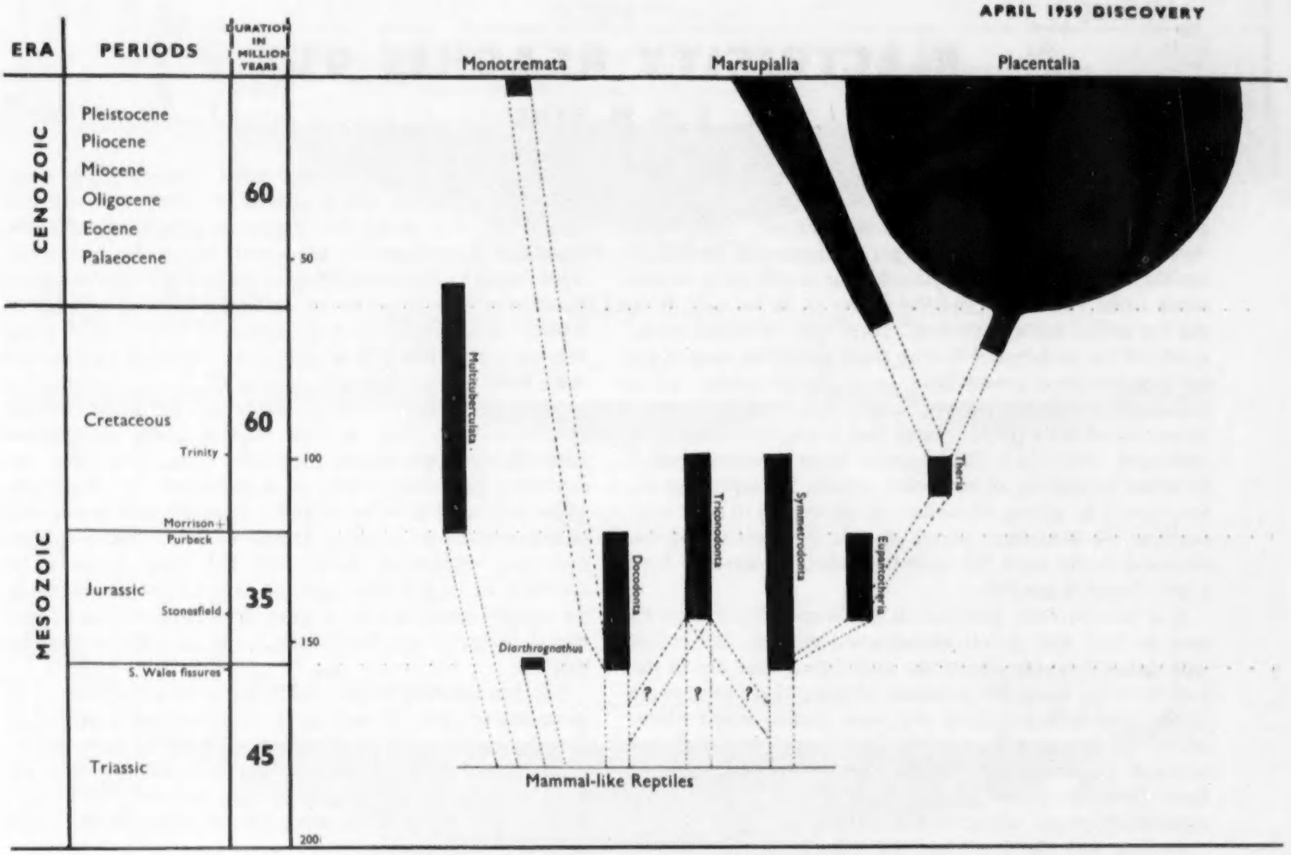


FIG. 11. Suggested family tree of the Mesozoic mammals.

represent yet another independent line of evolution which became extinct before the fully mammalian grade of organisation was attained.

CONCLUSIONS

Thus we see that the mammalian type of jaw evolved independently along a number of different lines and that, consequently, the mammals are a polyphyletic group—by which is meant (Fig. 11) that mammals have no common ancestor which was itself a mammal. The common ancestor must be found among the reptiles. If we accept this we solve one long-standing problem. Since the main groups of the mammals are distinct at their first appearance (which, in two cases at least, was as early as the Upper Trias), their common ancestor must have lived in the Middle or Lower Triassic. But here we have a good fauna of mammal-like reptiles. These are at a much more primitive level of evolution than we would expect if they had to evolve into mammals and then into the different mammalian groups before the end of the Trias. If the mammals are polyphyletic this difficulty vanishes.

These South Wales Mesozoic mammals have added a great deal to our knowledge of the origin and classification of the Mammalia. Of great interest is the number and form of their teeth and the probable relationship of the docodonts and monotremes. Most important of all, however, is the evidence of a double-jaw articulation and the support that this gives to the theory of a polyphyletic origin of the mammals.

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ELECTRICITY REACHES OUT

J. H. M. SYKES

At the Montreal Sectional Meeting of the World Power Conference, in September 1958, three trends in electrical power transmission were clearly brought out. First, there was the need to envisage longer transmission routes, to enable the vast untapped hydroelectric potentials in remote areas to be harnessed, and the power to be brought in to the industrial areas. Secondly, there was universal recognition of the problem of finding fresh routes for large high-voltage overhead power lines in industrial areas, and in particular in the vicinity of large cities. Finally, it was agreed by all the experts present that it was becoming more and more desirable to link together large power networks, to achieve economy of operation, mainly by improving the load factor by taking advantage of differences in peak load timings. A secondary factor in this last feature of the situation is the need for nuclear stations to have as high a load factor as possible.

It is not the basic function of the World Power Conference to deal with power transmission matters, but rather with general energy situations; and thus it was not in the papers of the Montreal Sectional Meeting that the answers to the problems posed by the three trends noted above could be found: nevertheless, experience at the International Conference on Large Electric Systems, held in Paris every two years, and in other fields of power supply engineering, shows where the answers may lie.

Dealing with the first trend, the need for longer lines to reach out to remote hydroelectric power sites, there are two factors involved. The first is the sheer question of distance of power transmission, using any kind of system. The second is the problem of bridging natural obstacles such as great rivers or lakes, mountain gorges, or even densely populated areas where overhead lines nowadays cannot be built.

POWER TRANSMISSION OVER GREAT DISTANCES

The first problem, relating to the sheer distance of power transmission, is being solved in two ways. With normal three-phase alternating current system, such as the British grid system, there is a distance limitation which relates to the physical constants of the circuit. A line could be compared to a simple electrical circuit made up of capacitances and inductances. When the values of these are altered, in a model network, a stage will be reached where the effect of these constants will be such that the power factor—the angle of lag or lead of the current in relation to the voltage—becomes so far from unity that stable operation of the line becomes impossible. This is due to the need for synchronising current to flow, in addition to the main power transmitted, to hold the A.C. generators at the two ends in step with each other. Above about 250 to 300 miles, stability is the main limiting factor in long-distance power transmission.

Steps have been taken to break down this barrier by the use of devices to correct the influence of the physical constants of the lines on the power transmitted. Chief among these is the series capacitor ("condenser", as these devices used to be called) placed in series with the line about half-way along its length, to compensate for the reactance introduced by the constants of the line itself. This results in a distance of up to about 600 miles becoming feasible with a single series capacitor station, and (as in Russia) some distances in the region of 1500 to 2000 miles becoming practicable if several series capacitor stations are introduced along the length of the route.

Series capacitor stations, however, introduce further complications. They usually require costly substations with highly complicated protective gear; and there are switching problems if they have to be cut out of circuit. Moreover, a given value of series capacitor will correct the characteristics of a given length of line. Often system operating conditions mean that the lines have to be switched in such a way that the original length of line is no longer connected to a particular capacitor, and this means incorrect conditions which can give rise to further troubles.

For transmitting larger and larger blocks of power, it is necessary to raise the voltage if the transmission project is to be economic. It is nowadays possible to carry up to about 1000 MW on lines which work at 400 kV, and the Russians are now changing over their networks to 500 kV. In America experimental work on line voltages up to 650 to 700 kV is in progress.

CORONA PROBLEMS WITH HIGH VOLTAGES

There is, however, a limit to the increase of voltage, which arises from the corona effect. Very high voltages tend to give rise to discharges from the line, and these discharges not only involve considerable loss of energy, but in addition give rise to serious interference with radio and television and other communication services, as each tiny sharp point emitting a discharge is in effect an unregulated transmitter.

To combat corona losses it is necessary to increase the surface area of the charged conductors, as charges tend to accumulate at the smallest radii, and are obviously greatest at sharp points.

It is not practicable to increase the size of single conductors on overhead lines beyond about 1½ in. in diameter, and the method adopted is to use two, three or even four conductors joined together by spacing devices and situated about 18 in. or 2 ft. from each other, the whole assembly or "bundle" forming an electrical whole, spreading out the electrical charge over an increased area. In this way system stability is also improved as the reactance of the line is reduced. However, while improving stability and reducing corona loss these bundle conductors involve costly equipment and sometimes give rise to severe mechanical problems, the answers to which have not been completely ascertained.

Thus the transmission of power in larger quantities over greater distances by normal three-phase A.C. methods has

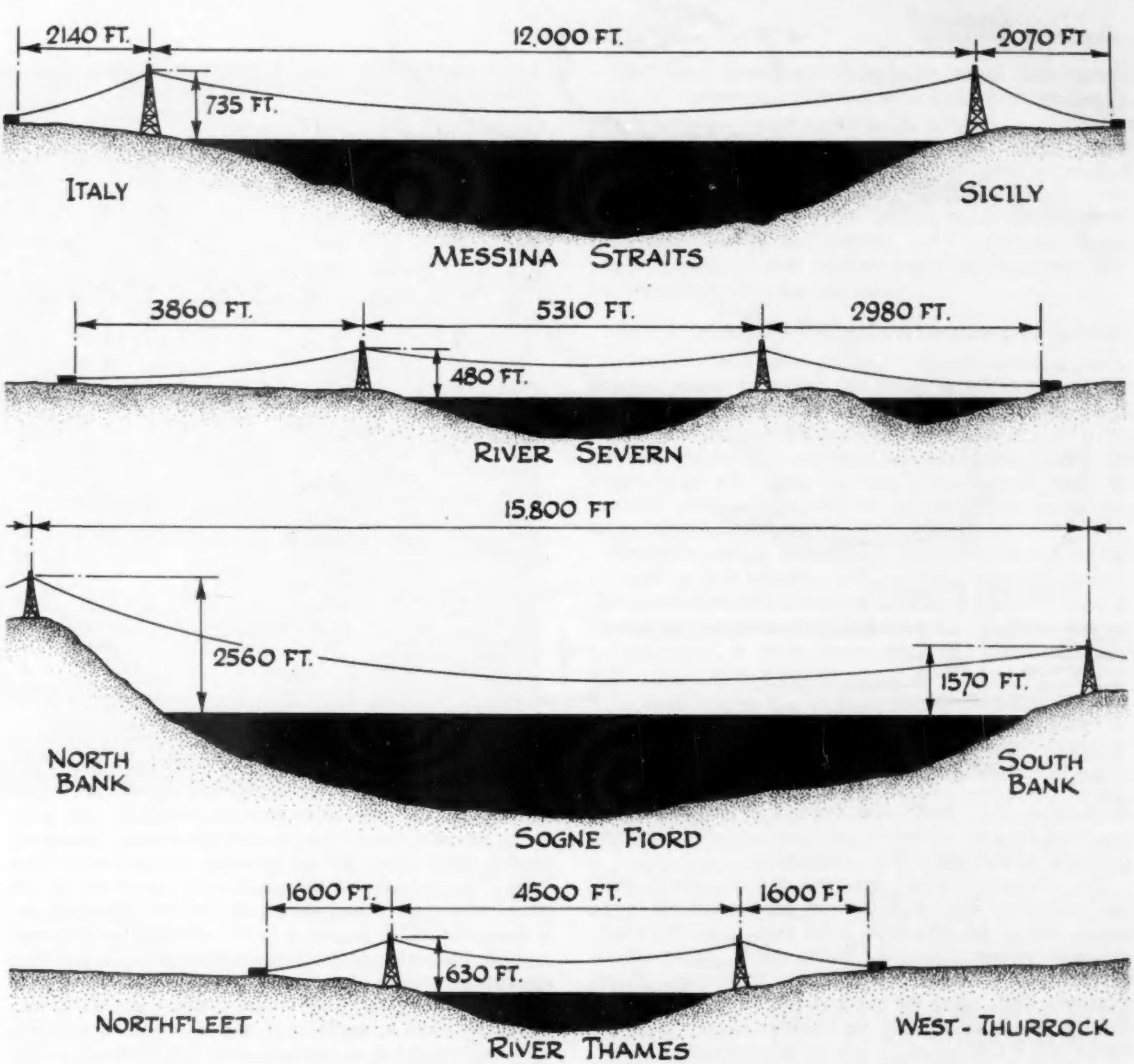

FIG. 1. A comparison of four of the world's principal "long spans", where overhead power lines are carried over natural obstacles. The lower illustration—the new Thames crossing—will be built in the near future, and the Severn crossing is under construction. The other two are in service.

at the moment a limit in distance of about 1500–2000 miles, and a limit in voltage (and thus in total power per circuit) of about 600 kV. It is to be expected that the voltage limit can be raised perhaps to 700 kV in the future, but the most informed opinion appears to indicate that voltages higher than 700 kV are not likely to be used for A.C. systems, for economic rather than technical reasons.

There is another aspect of power transmission which is becoming of increasing importance and we shall refer to this more particularly when we deal with the second major problem in bringing in remote sources of power. When the transmission route involves a major water crossing, exceeding about 25 miles in length, the A.C. system cannot be used. A cable is essentially of the nature of a vast capacitor, and the losses in the cable, with A.C., become so great when the length of any type of cable exceeds about 25 miles that it is not only uneconomic to operate but becomes almost impracticable from the point of view of stability of operation. Nevertheless, there have been some remarkable feats of submarine cable laying for distances below that figure in recent years for A.C. systems, including the 138-kV cables between the mainland of British Columbia and Vancouver Island, involving a sea crossing of 14·7 miles together with another associated crossing of 2·9 miles in length. Very severe problems in handling the large and extremely stiff cable needed for high voltages of this order had to be solved.

THE USE OF DIRECT CURRENT

The alternative to normal A.C. power transmission for extra high voltage, large-power long-distance projects is the use of direct current. This field of engineering has been

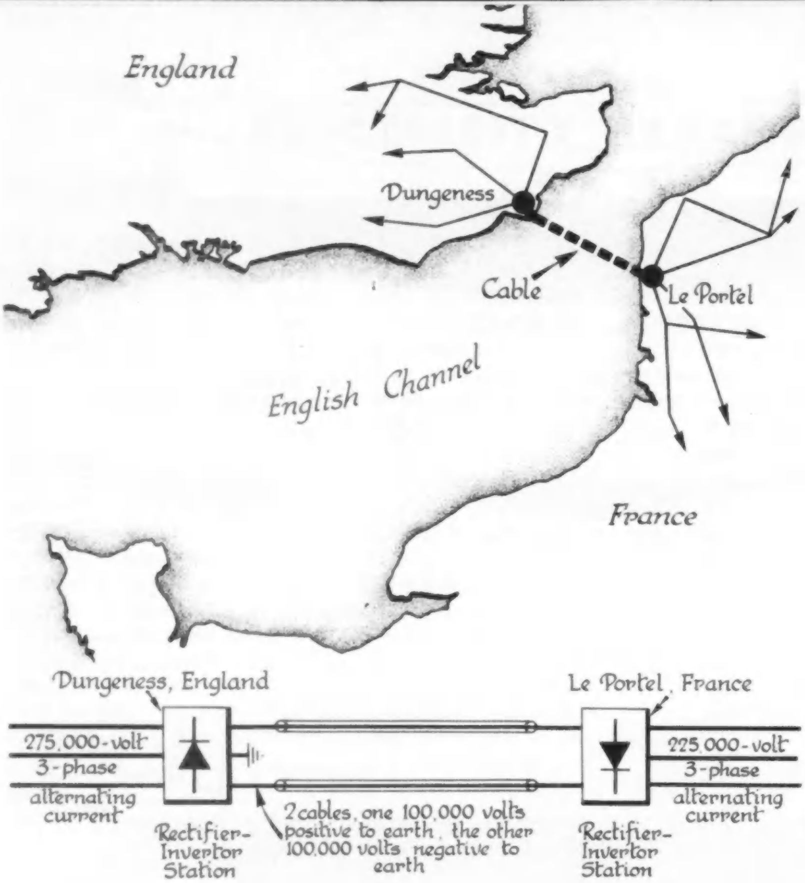

FIG. 2 (*left*). A schematic diagram of the cross-Channel power cable to be in service by 1960 or 1961. Work is now in progress on the equipment for the rectifier-invertor stations.

FIG. 3 (*right*). During the experimental laying of cables in the Channel, French divers supervised the details. The photograph on the right shows divers getting ready for similar work near Boulogne-sur-Mer. These divers are members of the French firm, Sogetram, which is a co-operative association operating as a community group with a staff of some sixty divers; each diver holds an equal share in the company.

subjected to very considerable research in the last decade, and there are some interesting examples of D.C. schemes at present in operation or under construction.

The advantages of D.C. are, first, that it requires only two conductors instead of three as for the normal three-phase system, and, moreover, if the two conductors are at an equal voltage above and below earth, under certain circumstances half the power can be transmitted if one conductor fails, using the earth as the return path. With the three-phase A.C. system, the breakage of one conductor means that no power at all can be transmitted. The D.C. system makes better use of the insulation of the cable or overhead line, because the A.C. line or cable has to be insulated for the peak voltage of the A.C. voltage wave, whereas the effective voltage is only $\frac{1}{\sqrt{2}}=0{\cdot}707$ of this figure. For the D.C. circuit the whole of the insulation is effectively used. With D.C. there is no problem of system stability, and it is theoretically possible to transmit power over any distance required, even scores of thousands of miles; for example, a D.C. cable across the Atlantic and into the Canadian water-power regions is perfectly practicable on technical grounds but not necessarily on economic grounds. The D.C. system is capable of coupling two networks of different frequencies and has the great advantage (particularly in the case of hydroelectric stations where the frequency may have to be varied slightly for hydraulic reasons) of enabling the link to be set to give an exact and constant power flow whatever may be the conditions in the networks at either end.

The disadvantages of D.C. include the cost of providing the mercury arc valve converter stations at the two ends of the line, and the fact that no suitable switching arrangement is yet available for any possible tappings on the line itself. With A.C. all switching is based on interrupting the circuit when the current passes through the zero point, as it does on each cycle, but with D.C. this is obviously not possible. A further problem in D.C. schemes is the fact that the reactive power at the receiving end, required by the lagging nature of the power factor of most industrial loads, cannot normally be provided by the D.C. to A.C. conversion equipment, and has to be made available either by banks of capacitors or by synchronous condensers—rotating machines involving their own problems of cost and maintenance.

For these reasons D.C. is not, in the present stage of the art of power transmission, normally considered for distances on land of less than about 300 to 400 miles and powers of under about 500 MW, although under certain circumstances very large power might be carried more economically by D.C. over shorter distances.

EXISTING DIRECT-CURRENT SCHEMES

At present, there are in the world two high-voltage D.C. power transmission schemes in operation and two under construction. The Gotland scheme carries 20,000 kW of Swedish hydro power to the island of Gotland, and operates perfectly satisfactorily. In Russia the experimental scheme between Moscow and Kashira carries 30,000 kW over about 72 miles, and uses two land-laid cables. The scheme for the crossing of the Channel with a D.C. cable linking the British and French electricity supply systems and pro-

viding a transfer of 160,000 kW in either direction, using two single-core cables, is under construction, and is expected to be in operation by 1960 or 1961. In the U.S.S.R. a scheme for coupling the Stalingrad hydro-electric station to the Donbass region over a distance of 292 miles using a line voltage of 800 kV (400 kV positive to ground, 400 kV negative) is also under construction. There are proposals for linking the North and South Islands of New Zealand with a D.C. submarine cable, and test lengths have already been laid. There is also a proposal for bringing surplus hydroelectric power from Yugoslavia to the southern part of Italy, across the Adriatic Sea. Other D.C. links which have been discussed include the bringing-in of Norwegian hydroelectric power to Denmark by means of a cable between the two countries, and the exploitation of the surplus power available in Iceland by means of a link to Scotland.

The probable development of D.C. for power transmission will be that large projects in the U.S.S.R. for bringing in Siberian water power to the European centres of industry will point the way to solving the economic problems which tend to hinder its development for other than submarine cable at the present time. Then we may well see links between the North African hydrolectric power resources, some of which are enormous, and the European continent, by means of submarine cable, with 1-million-volt D.C. overhead lines striding across Italy and France to link up with the heavily loaded electrical grid systems in Western Europe. In Canada it may also be expected that the next few decades will see long-distance D.C. lines linking the untapped hydroelectric resources to the centres of population.

The second problem in bringing in power from remote points is the physical problem of bridging gaps created by obstacles such as water crossings and gorges.

We have seen, above, how a D.C. system enables major water crossings to be accomplished, and it was noted that a crossing of about 25 miles was practicable using the A.C. system. However, any cable system must inevitably be more costly than an overhead line, and it is only after every possible overhead line solution has been examined that a cable project has to be considered.

"LONG SPANS" IN TRANSMISSION LINES

There has been some startling progress, in recent years, in what might be called the "long span" technique for carrying overhead electric power lines over distances much greater than those which had previously been thought to be possible. In normal overhead line practice, even for the highest voltages, spans do not exceed about 2000 ft. between adjacent supports. In practice, most spans are nearer 1000 ft. in length.

When it comes to envisaging a crossing of an arm of the sea such as that between Sicily and the mainland of Italy (the Messina Straits) where the distance is 12,000 ft., severe mechanical problems begin to intrude. In Great Britain a "long span" is under construction to carry the 275-kV super grid system across the rivers Severn and Wye, where the principal span is 5310 ft. in length. In Canada a line carrying power to the aluminium processing plant at Kitimat crosses a gorge with a span of 6560 ft.; while the longest "long span" of all is in Norway, where the Sogne Fjord is crossed by four conductors of a 60-kV line having a span length of 15,800 ft., only just short of 3 miles.

The basic problems encountered in designing long spans can be summarised under three headings. First, there is the still unknown effect of vibration; secondly, the provision of a strong enough conductor to carry its own weight and to withstand the very high wind and vibration stresses it may encounter; and next, there is the problem of erection to be considered.

Although much research has been carried out in the leading electrical countries, it is still not possible to provide a scientific evaluation of the behaviour of a given conductor in service. There have been surprising cases, within the present writer's personal knowledge, of conductors which have commenced to vibrate (rather like telephone lines which give out a humming noise) and have built up the vibration until the conductors reach the alarming condition known as "galloping" or "dancing", when it is quite possible for a line in which there is 12 ft. between the phase conductors to suffer severe damage through the wires touching each other and flashing over, during this violent exercise.

To combat vibration, empirical methods have to be used, and there are two basic systems currently adopted—vibration dampers and the use of armour rods.

Vibration dampers consist of weights at the end of a springy wire which is coupled at its centre-point to the conductor itself. As the conductor tends to vibrate, it carries with it the clamp and this clamp transmits the motion to the two weights, which are effective within limits in damping out the vibration. The type of damper just mentioned was originally developed over thirty years ago

by an engineer named Stockbridge, and has remained substantially unchanged in design ever since. The design is successful, and Stockbridge dampers are very widely used in Great Britain and abroad, but it is still true to say that no one knows exactly what size of damper and how many dampers at what intervals are necessary to make absolutely certain that a particular span, whether normal or longer than normal, will be completely prevented from vibrating under any possible conditions. A series of tests now being carried out in the United States on dampers and on the types of spacer to be used for bundle conductor lines (where vibration can give rise to even greater vibrational problems than those with single conductor lines) may lead to more accurate answers to the questions posed by conductor vibration effects than have hitherto been obtainable.

Armour rods consist of a bundle of wires or rods of the same material as the outer strands of the conductors (usually aluminium) twisted round the conductor itself for a distance of 5 to 20 ft. on either side of the clamp which secures the conductor to the insulators at each tower. These armour rods damp out the vibration in a manner generally similar to the Stockbridge damper, but offer the additional protective feature of ensuring that if a flashover occurs between the conductor and the earthed metal of the tower, the burning will be confined to the armour rods, which can be replaced easily, and will not affect the vital conductor material itself. They are, however, more costly and difficult to apply than vibration dampers.

CROSSING THE MESSINA STRAITS

Vibrational effects on the crossing of the Messina Straits are dealt with, on this span of four conductors suspended from towers 735 ft. high, by means of specially designed dampers made up of lengths of the same conductor as that used for the crossing span itself, festooned together and joined to the main conductor. On the Severn crossing very large Stockbridge-type vibration dampers have been specially designed and seven of these are being installed at 8-ft. spacings at each end of each conductor.

The release of snow loading from a long overhead line span can give rise to serious whipping troubles, and again only by the relatively empirical methods of widening the spacing between conductors, strengthening the wires and the associated joints and anchor clamps, and similar "brute force" methods, is it possible to be certain that such installations will operate reliably.

The Messina Straits conductor is remarkable in itself, and exemplifies the problems which have to be faced by the designer of equipment for long spans. The span is such that the weight of a conductor could easily be so great that the sag would be beyond the permissible limits, and it was necessary to evolve a conductor of the utmost strength and lightness. Obviously high-tensile steel would have to be used, but if this material alone had been employed there would have been danger of heating due to the passage of current. The Italian engineers, after a lengthy series of tests, evolved a conductor made up of nineteen strands, twisted together, each strand consisting of six steel wires of 0·071 in. in diameter laid over one aluminium wire of 0·068 in., while there were also steel fillers to make up the circular conductor, of six steel wires each 0·083 in. in diameter. This complex conductor weighed only 1·8 lb./ft. when filled with grease, and has an overall diameter of 1·055 in. Its breaking strain is 120,000 lb.

For the Severn crossing, now under construction, two towers 480 ft. high—almost as high as Blackpool Tower—are being built and there will be seven conductors—two three-phase circuits and an earth wire to act both as a lightning protection device and as a spare conductor in case of failure of one of the other six. In this case a different technique has been adopted for the conductors, where the breaking strength is 227,000 lb. and each wire is made up of an enormously strong steel core comprising ninety-one strands of steel wire with a diameter of 0·113 in. covered by seventy-eight aluminium wires of the same diameter. This weighs 4·3 lb./ft. and has an overall diameter of 1·695 in. It is, so far, the strongest conductor ever made; but a projected crossing over the River Thames near London is to employ an even stronger conductor which undoubtedly will be the largest ever made. The span will be 4500 ft. and the towers will be 630 ft. high.

As we have already seen, combating vibration and designing a suitable conductor are the most difficult problems apart from erection, when long spans are under consideration.

In the case of the longest span of all, across the Sogne Fjord in Norway, erection was simplified to some extent, at least, by the fact that the heights of the two banks of the fiord were different, the north bank being at a height of 2560 ft. above sea-level and the south bank 1570 ft. This meant that once a pilot wire had been stretched across, the running-out blocks and the conductor itself would be assisted by gravity. For this span the four cables were of steel, three carrying the current and one acting as reserve. Each cable had thirty-seven strands, and the sag reaches the amazing figure of 1870 ft., leaving a minimum free height, under any conditions of temperature or snow loading of 196 ft., at the centre of the fiord.

The Canadian long span across the Kootenay river, 2 miles in length, employed galvanised steel wire also, and the cables were 1·25 in. in diameter.

For all those long spans, and for many ordinary spans, erection equipment grows more scientific as each new major transmission-line project is attacked.

Specially designed winches are used to pay out the conductor so that it never touches the ground, where it might become damaged, and so that it is never tensioned up to an excessive level. Specially designed handling equipment for the cable drums has been evolved to enable the utmost rapidity of erection to be achieved. Transmission-line towers, conventionally made of galvanised steel angle, are sometimes made up of tubular steel, the tubes being filled with concrete. Wood pole lines are being used for higher and higher voltages, to cut costs, to speed erection, and to facilitate change of route if required. Modern methods of impregnating wood with creosote and other anti-rotting compounds have resulted in poles having much longer lives than in the past.

It seems that spans across rivers, channels, and gorges can now be accomplished for distances of up to about 3½ miles, while (with the use of D.C.) there is no limit to the length of submarine cable that can be laid; but for such cables the magnetic effect created by a direct current can affect ships' compasses, and this means that the "go" and

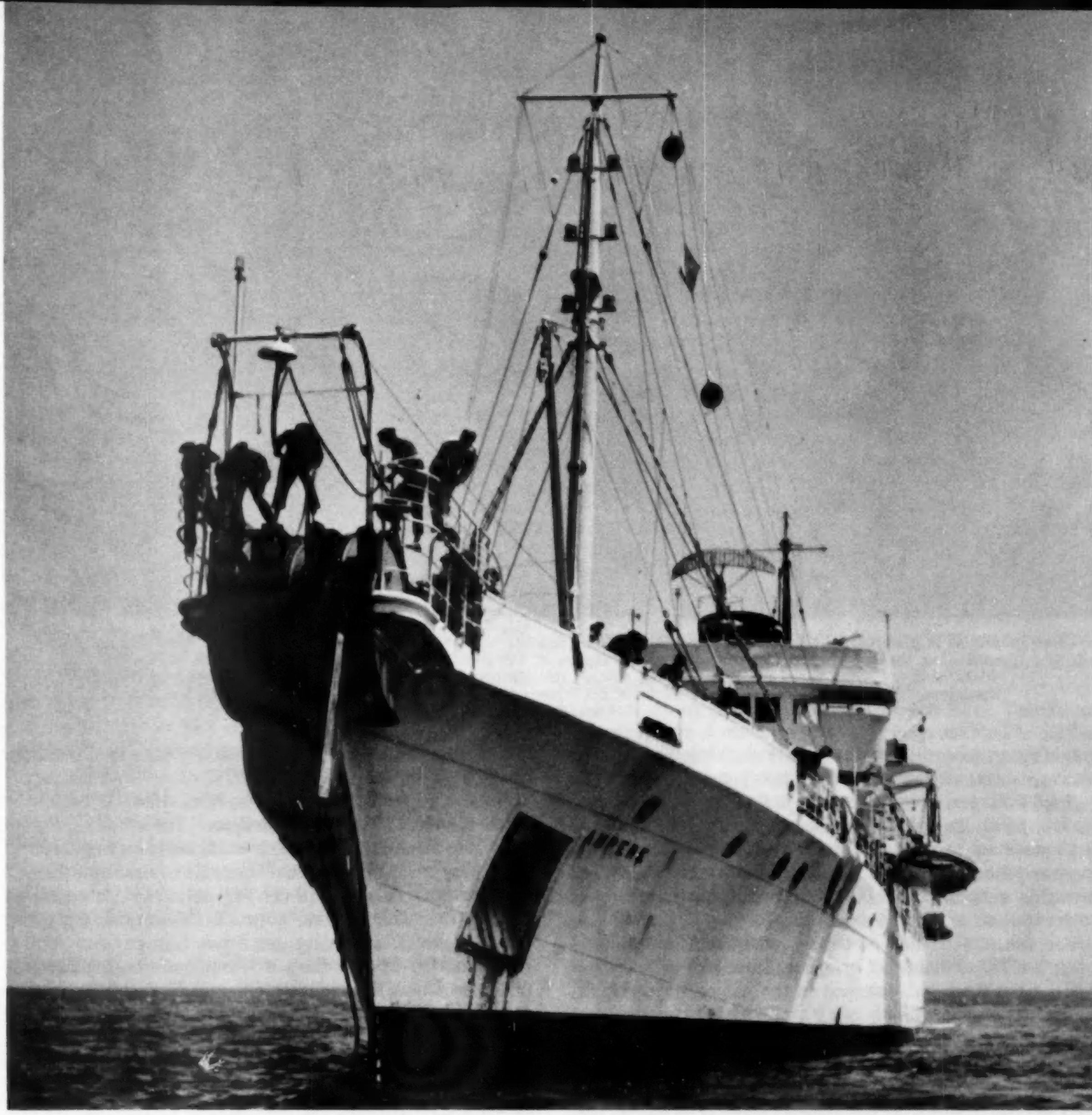

FIG. 4. The French cable ship *Ampère* during recent cable-laying trials.

"return" cables must be laid closely together. In the case of the Channel cable, the distance has to be 10 ft., and this again involves the development of special laying techniques, which might have to be still further developed if there were proposals for laying cables in very deep water.

PROBLEMS OF FINDING POWER TRANSMISSION ROUTES

The second trend noticed at the Montreal Sectional Meeting of the World Power Conference in regard to transportation of large blocks of electrical energy was the difficulty of finding wayleaves through intensely built-up areas. This difficulty is particularly pressing in Great Britain. It is now virtually impossible to bring further transmission lines within about 10 miles of the centres of large cities such as Birmingham, Manchester, and Glasgow, and 15 miles of the centre of London. Although the cost of undergrounding a 270,000-volt super grid circuit is approximately sixteen times the cost of an overhead line, it will be necessary to consider a great deal more undergrounding in the near future. The demand doubles every ten years, and as it exists mainly in the centres of industry, and as each rebuilding programme in a city area brings three or four times the electrical demand attributable to the previous dwellings, obviously more power must be brought in to these areas. This problem exists also in other parts of the world; but not every country is so particular about amenities. The present writer was somewhat surprised to see a 100-kV main overhead transmission line brought right into the heart of Moscow, within sight of the Kremlin itself.

The answer to this problem can only lie in evolving less expensive types of high-voltage cable. Here there is hope that the plastic cable may prove to be the answer. British

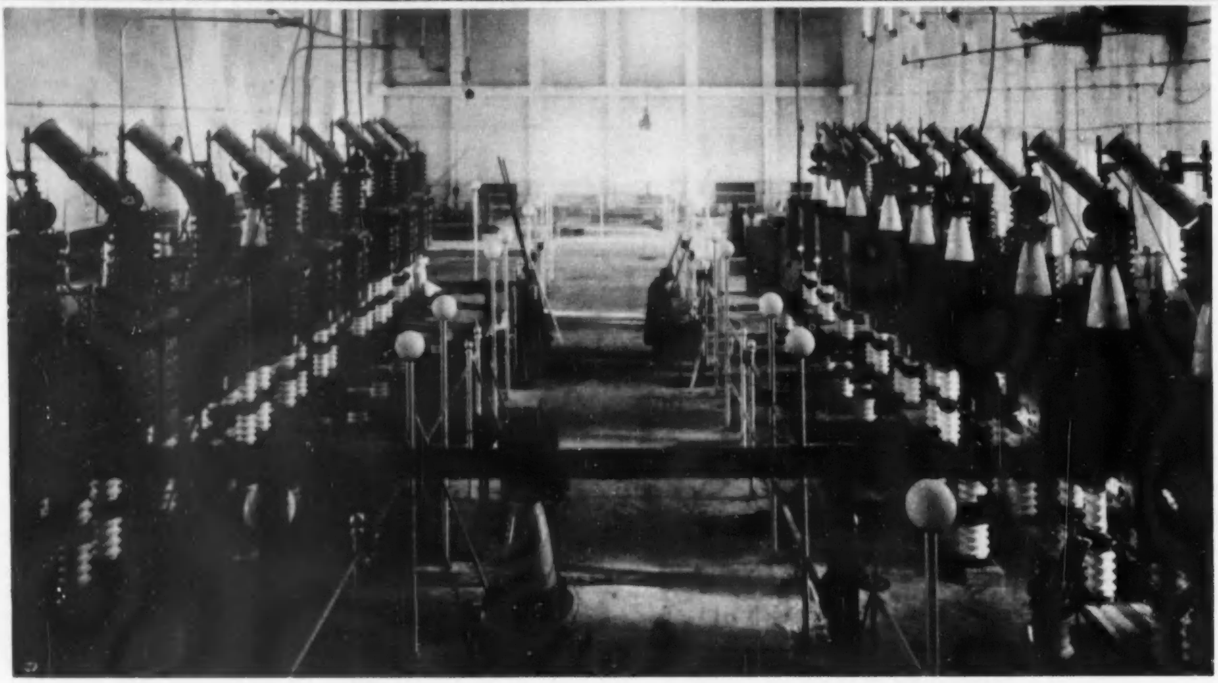

FIG. 5. A photograph, not previously published in any journal outside Russia, of the experimental valve-testing station on the outskirts of Moscow, at the termination of the direct-current cable to Kashira. The valves, for 90,000-volt operation each, are seen on each side of the centre gangway, each valve being supported on white insulators. The main anode insulators of white porcelain on the right and brown porcelain on the left, can be clearly seen.

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The use of D.C. may receive a considerable impetus as a result of this difficulty of bringing power into urban areas. Apart from the losses inherent in the use of lengthy high-voltage A.C. cables, there is also an operational problem which occurs when the system is lightly loaded, as during the night. The capacitance of the cables gives rise to an unstable condition at the generator terminals, and expensive shunt reactors have to be used to correct this operating defect. These would not be necessary if D.C. was used. Moreover, with a heavily loaded network the short-circuit power which might be fed into a fault, becomes so great that the protective gear and switchgear, in A.C. systems, is stretched to its very limit, and is in any case extremely complicated and costly. Direct current would mean that the fault power could be electronically and instantaneously limited, thus solving many problems at once.

INTERCONNECTING LARGE POWER SYSTEMS

The third and final feature of the trends revealed in the World Power Conference Meeting related to the pressing need for greater interconnexion between power systems. This may or may not involve lengthy transmission lines, but it does involve lines with large power-handling capacity.

The basic reason underlying this trend hinges on the world problem of improving load factor. At present, the average load factor in industrialised countries is of the order of 40%. This means that for 60% of its time the highly expensive generating plant is standing idle. It has to be there to meet the peak demand. The whole idea of economic feasibility of the connexion between England and France by means of the Channel cable arises from the fact that the peak demands in the two countries are separated by only one hour in time. If one could imagine a gigantic power network spreading out from Europe into Africa, Asia, and the Middle East, it is obvious that the different time zones and the different climates, industrial demands and personal predelictions applicable to these areas would give a very much greater diversity of peak demand, and this would in turn improve the load factor. The ideal condition could probably never be reached, where every generating unit was delivering full load all the time—sometimes sending out power for local demands, sometimes feeding it over a thousand-mile length to a demand in another part of the world. But each interconnexion, spreading out from a parochial scale to a national network, and from a national to an international grid system helps in providing electricity for everyone at the cheapest possible price.

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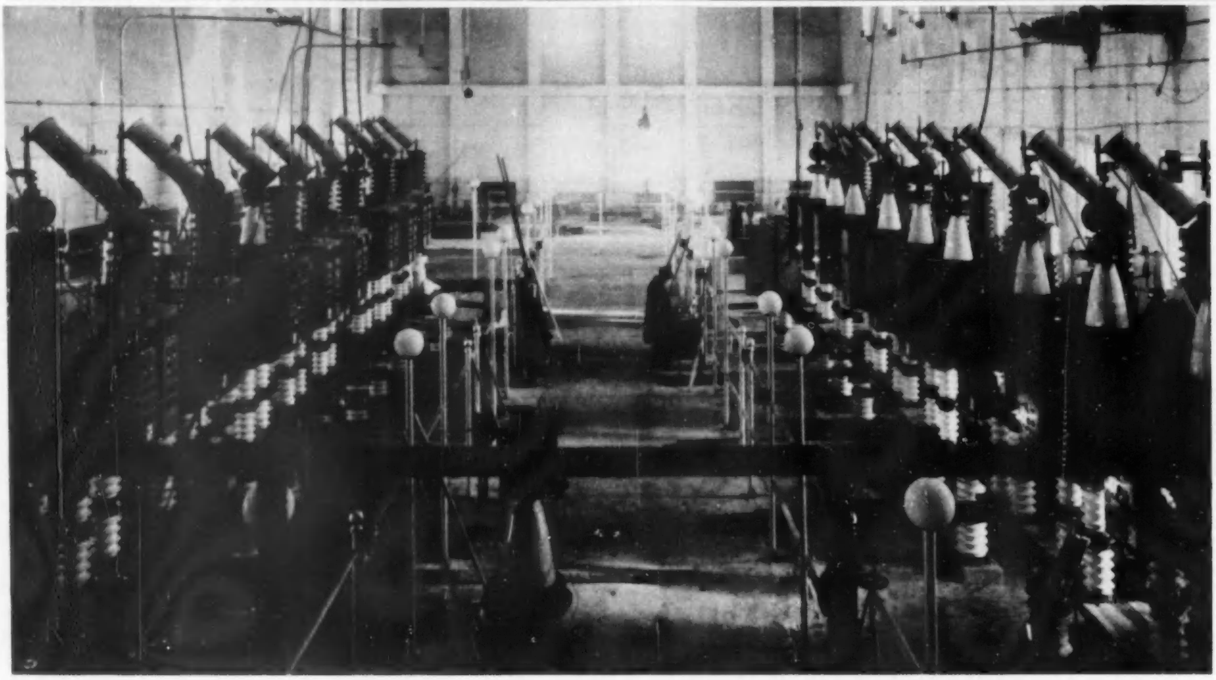

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INFORMATION THEORY AND THE VISUAL SYSTEM

F. H. GEORGE

Department of Psychology, University of Bristol

Everyone knows the enormous importance of language to the human race. Language has enabled the human species to accumulate a vast amount of knowledge which it has more or less successfully transmitted from generation to generation. This transmission of information (we think of the official process as "Education") has allowed us to *learn* from verbal description, as well as by direct acquaintance. Thanks to language (and by language we mean maps, codes, and pictures as well as words) we do not have to go to Tierra del Fuego to know that Tierra del Fuego exists. We may agree that this is fortunate, otherwise it would never have existed for most of us.

Languages then are a great blessing, but they have their difficulties and vaguenesses too, as philosophers will testify; since they have used millions of words trying satisfactorily to define *meaning* and *truth*, without much success. The most recent development in language is the measurement of the amount of information which may be passed by a message.

The idea of measuring information really came from engineers and scientists who are concerned with technical problems of sending information along certain channels, in a highly specialised way. Such people as telecommunication engineers have been principally concerned with these advances. Radio and television are other obvious sources of information, as well as people who write books and articles. The whole process can be illustrated as in Fig. 1.

INFORMATION THEORY

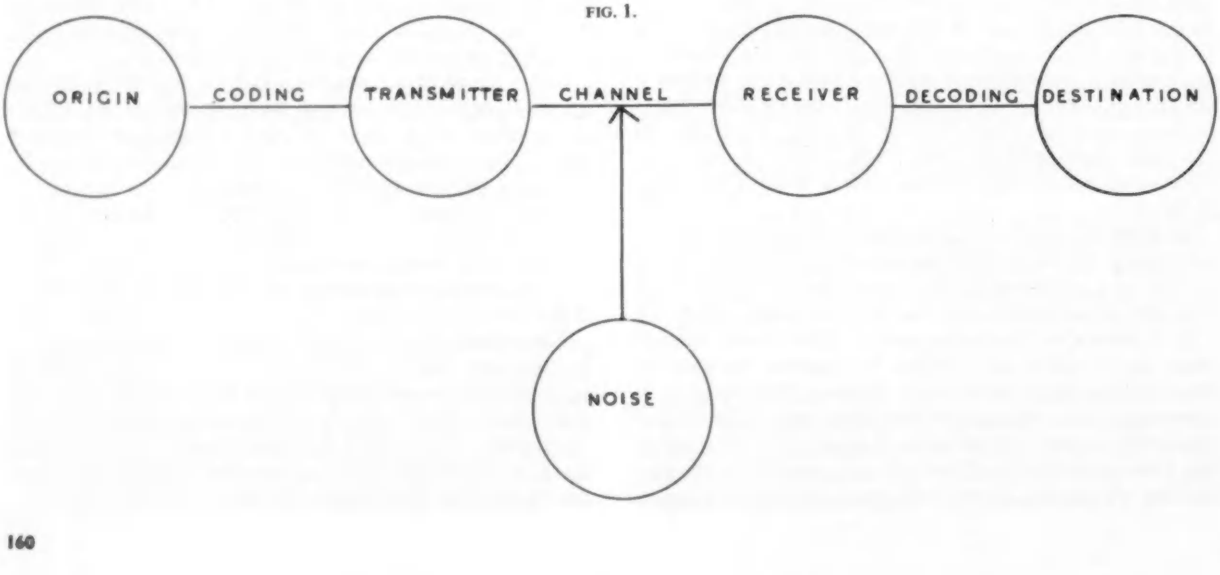
The importance of being able to *measure* information may not be immediately obvious. One can only say that the whole of modern science has progressed on the ability to make systematic measurements. Measurement means precision and allows prediction, and this is the aim of science.

The applications of information theory have been limited so far, and we may expect the full force of the work to increase with each succeeding year, and the one we shall discuss is the first application to the visual system.

Anyone who has played the game of circulating a message through a group of people knows how distorted the information becomes before the message returns to the originator. A casual remark such as "Charlie has a slight cold" soon becomes "Charlie died a horrible death of cold, while in the Arctic". Rumour spreads in this way, and rumour is first cousin to propaganda, and these are both forms of effective control, by circulation of information. To illustrate this simply, when X says to Y "pass up the bricks", Y will only follow the instruction if he understands it, and perhaps not even then. If he passes up something else, you might attribute his failure to not hearing—what scientists call a *noisy channel* may have made the message unclear. If X now shouts the same instruction again and Y still passes something else, then it is clear, providing he is not being exceptionally awkward, that he doesn't understand the meaning of the word "bricks". He certainly seems to know what "pass" means. A demonstration, or a few words of explanation, will now put the matter right. Such messages, even conversations, can be measured for their information content.

Before we try to explain the measurement of information, it will be wise of us to bear in mind two things. In the first place, language is a code system for our *ideas*, and the code has to be broken down by the person who listens to the words we use. The language in which we choose to code our ideas can be further coded, any number of times. This is very clear when we send a message by Morse code, or by semaphore, or if we happen to be tick-tack men, we will have yet another code. This matter of codes will be discussed further, but we should realise its basic importance before the attempt to explain the method of measurement. Our second preliminary point is that if we take any word and give it a precise meaning (the sort of thing we do when we measure something), then we have to pare it

FIG. 1.



down in some way. Think of the word "love"; this means many different things to the man who loves his job and the man who loves his wife, or the man who loves science, literature, or golf. There are resemblances, but there are also differences between the meanings, and our process of measuring will probably only apply to one particular aspect. So it is with information; we mean the word information to be understood in a somewhat limited sense.

Now to illustrate the method of measurement. Consider the situation where you have a friend who is about to have a baby, and there is no reason to expect a boy rather than a girl. We say in such circumstances that a boy and a girl are equiprobable (the same as with heads and tails when we toss a coin), and the message telling us whether it was a boy or a girl would contain *one bit* (short for binary digit) of information. One bit of information tells you which of the two equally probable events has occurred.

Now let us try our hand at passing a little more information than one bit. Let us suppose that we add one casket to our production of the *Merchant of Venice* and then there are four possible places for the hoped-for "message of love", and as far as we know they are all equiprobable. If we bribed someone to tell us which casket is the correct one, they might have passed us a note saying "the bronze casket is the one".

Those who have no skill in solving mathematical puzzles are asked to take it, on trust, that this information, compared with the previous example, is worth two bits. If there had been 8 caskets our message would have been worth 3 bits, and 16 caskets would implied a relative value of 4 bits. If they are all equiprobable, all we have to do is to divide the number of cases by 2, to divide the answer to that sum by 2, then divide the answer to that sum by 2, and go on with the process until the answer to the final sum is 1. The following diagram may make this easier to understand:

BITS	1	1 1	1 1 1	1 1 1 1
CASES	$\frac{2}{2}=1$	$\frac{4}{2}=\frac{2}{2}=1$	$\frac{8}{2}=\frac{4}{2}=\frac{2}{2}=1$	$\frac{16}{2}=\frac{8}{2}=\frac{4}{2}=\frac{2}{2}=1$

The rigorous mathematical definition of information is given by:

$$H=-k\sum_{i=1}^{n}p_i \log p_i, \tag{1}$$

where the p's are the probabilities associated with the possible choices—the four possible caskets in our example. The symbol $\sum_{i=1}^{n}$ simply means the sum of all the expressions of form $p_i \log p_i$ from $i=1$ to $i=n$. Thus the right-hand side of formula (1) is shorthand for

$$p_1 \log p_1 + p_2 \log p_2 + \dots + p_n \log p_n. \tag{2}$$

If each possibility is not equiprobable, then of course we get a slightly more complicated expansion of the right-hand side of (1). The logarithm in *all* cases is to base 2.

Thus we may have a simple system of two messages, a and b, where the probability of a is $\frac{3}{4}$, and b is $\frac{1}{4}$. Suppose each symbol takes 1 second to transmit so there are no difficulties over the weighting constant k, then, by (1)

$$H=-\frac{3}{4}\log\frac{1}{4}-\frac{1}{4}\log\frac{1}{4}, \tag{3}$$

which can easily be shown to be equal to 0·811, which is the information content of the channel. We can, of course, measure channel capacity and other aspects of communication, but this is unnecessary to our discussion of vision.

By such means, we can achieve a precise measure of what information has passed in a situation, although we also have to know in advance all the messages that *could have been passed*. When one *thinks* of the two bricklayers again, one *realises* that there are a large number of possible things one *could have said* to the other. This presents technical difficulties that we shall not worry about here, since they can largely be solved.

It will be clear that the study of psychology and physiology will be directly affected by these studies of information. Indeed in many respects human beings are machines for the encoding and sending of information and the decoding and the receipt of information, or can be regarded as such. Then a whole group of humans makes up a complicated network of information, like our rumour game; the subject-matter for the social psychologists as well as the novelist. Let us now forget for a moment the speakers and listeners and consider the languages they use.

CODING

To decode a language, we depend upon the repetition of certain symbols. If, in a letter, you see the word "anchor" occurring two or three times, when we come to a word we can't wholly read, but starting "an . . .", and if it is about the same length as "anchor", then it is a fair guess that the word is "anchor", even if the context does not already make this clear. The point is that by making assumptions of this kind we are right far more often than we are wrong, and we can break codes in just this way.

The frequency with which certain letters occur in English are part of the pattern of recurrence that makes code-breaking possible. In English, *E* occurs very much more often than any other letter, with *T*, *A*, and *O* following close behind in that order. Right at the other end and very rarely used are *X*, *J*, *Q*, and *Z*. Naturally, it is not only the frequency of letters that makes up a language. It is the combination of letters, especially into words, that matters. A simple example of the sort of relation we have in mind is given by such rules as *U* almost always follows *Q*, and *I* before *E* except after *C*.

From the technical point of view we shall not forget that the letter-space, the word-space, and all the punctuation marks, are part of the language code. Bearing this in mind, we shall not be surprised to find that with a table of random numbers, and following the frequency of letters and words, it is possible to produce writings that look to be quite good English.

The *Code Capacity* of a channel has to be appropriate to the passing of a code, and the code capacity in the simplest case, where all the symbols used are of the same length, has an especially simple form. If we have an alphabet with 16 symbols each of the same duration, and

thus each carrying 4 bits of information, the capacity of the channel is $4n$ bits per second, where the channel is capable of transmitting n symbols per second.

We shall now give a simple example of a common form of coding of an artificial language into binary code, which uses the digits 0 and 1 only.

Suppose the following six letters occur in the alphabet with the frequency given against them, as a percentage.

A	35%	*C*	15%	*E*	10%
B	20%	*D*	12%	*F*	8%

They are already placed in order of priority; if they were not, we should do this first of all. Then we combine the two letters with the lowest frequencies. Here this is *F* and *E* to make *G*, say, with a frequency of 18, and we now place *G* in its correct place in the list. Then we combine the new bottom two, which are *C* and *D*, to make *H*, which is 27, and this goes to its proper place. The list now reads:

A	35%
H	27%
B	20%
G	18%

We now combine *G* and *B* to make *I* with 38, and then *A* and *H*, to make *J*, which has frequency 62. The final list has only two members:

J	62%
I	38%

We now code *J* as 0 and *I* as 1, and since these are both derived symbols, we look at their derivation. Thus *J* is composed of *A* and *H*, and we code these as 00 and 10 respectively. *A* is a letter of the original alphabet and has now been coded, *H* is derived from *C* and *D*, which become 100 and 101 respectively. *I* comes from *B* and *G*, which are then 10 and 11, and *G* in turn from *E* and *F*, which become 110 and 111 respectively.

Thus the original alphabet gets the following code:

A	00	*C*	100	*E*	110
B	10	*D*	101	*F*	111

This code has the advantage of giving short code symbols to the most frequently used letters and the longest code symbols to those least often used, and this is generally useful for relatively economic transmission. Different codes will have different advantages, and it will depend on which aspect of our transmission we wish to maximise, which code is used.

Careful study of codes and languages has revealed another interesting property, which has been called *redundancy*. We say that languages have different degrees of redundancy in so far as they increase the length of our messages solely through the conventions of the language. A code or a language (there is really very little difference) that is highly redundant is a great disadvantage if we are in a great hurry, or if we have to pay the cost of the telegram ourselves. What we lose there on the roundabouts, we gain on the swings though, since a language with a considerable measure of redundancy is one where we can miss some of the words and still not lose the whole sense of the sentence. Even a secret wartime code must have some redundancy for this reason, since the chance of either the receiver or transmitter making at least one mistake is very great, quite apart from losses through noise and other forms of interference.

We have said a great deal about languages and codes, and have pointed out that the information conveyed by a language can be measured, quite easily in the case of artificial codes referring to definite events, and even in more complex cases. The astonishing thing is that all our knowledge is closely bound up with language, and when we stretch the word language to mean gestures and all sorts of signs, then we include *all* knowledge.

Attempts by modern scientists to understand the workings of the human brain and to predict people's behaviour have made use of information theory, since it is quite convenient to regard the brain and the central nervous system as a giant encoder and decoder coupled to a storage system, rather along the lines of the large-scale computing machines. The nervous system picks up changes in the environment and transmits information in the simplest of codes to the storage in the brain, where the message, in the form of pulses in the nerve, is translated into a state of feeling or seeing something occur, and the response is coded and sent to the muscles for action. The recognition of the wild bull suggests that the leg muscles should start operating as quickly as possible. It may seem curious that human behaviour can be described in terms of information flow, both inside the organisms and between the organisms, but this is the case.

THE APPLICATION TO THE VISUAL SYSTEM

An application of information theory to the visual system has been explicitly attempted by Anatol Rapoport and some part of such applications have been attempted by other writers including J. T. Culbertson. We must now try and outline the way such applications might be undertaken.

We can regard information as flowing between two points in a system. It is no longer a conversation between people, but an information flow between the retina of the eye and the visual cortex. We really need to know the anatomical structure of the visual system in advance if we are to study it as a communication channel, and this we do not wholly know. Furthermore, we might have undertaken a study from the point of view of messages initiated in the outer world, but for this we should need to know the encoding system that transmits the external messages into nervous impulses and this we do not know. Thus we must confine our analysis to the retinal-cortical pathways.

Some part of the coding of the retinal elements has been unravelled by physiologists, in that we know that the retina contains on-off-, on-, and off-cells, and these cells have their own characteristic responses. But even this is hardly sufficient to define the retina as an information source, since we don't know how the activity of retinal cells interact. This all implies that we must start with fairly idealised ideas about how the nervous system works.

We shall regard the retinal photoreceptor layer as a mosaic that could be specified by say, spherical polar coordinates, and use the shortest refractory period of all the

cells as our unit of time, then the effective mosaic at each instant, which we will call our time-unit, is uniquely specified.

If we say that each state of the retina is capable of carrying a message, then for n receptors there will be 2^n messages since any receptor can be in either of two states. If these receptors were all independent of each other, then the information content of the source would be given by the formula

$$H=\sum_{i=1}^{n} p_i \log p_i + q_i \log q_i, \qquad (4)$$

where p is the probability of any one of the receptors firing and q the probability of it not firing.

If there was always a 50–50 chance of any receptor firing, H would be equal to n bits per message. Now Polyak has suggested 10^8 as a probable number of photoreceptors and Fulton suggested 10^{-3} as an average refractory period. This leads to $H=10^{11}$ bits per second on the above formula and this is almost certainly far too big in view of what we know of the visual system.

The next step then is to consider, as does Rapoport, the possibility of regions sending messages, where the actual number of photoreceptors firing in each region constitutes the message. This gives us a more complicated expression for H, and then we can consider the interaction of the elements in the regions, which will make our expression for H more complicated still.

Physiologically we have a lot of evidence that suggests that the retina is highly organised, and that there is a great deal of interdependence in the successive states of the visual field. Looking at an object, we will, generally, under normal circumstances, see it from various slightly different angles successively. This implies a high measure of *redundancy* in the retina.

It is this redundancy that enables the visual system to operate at well below the level of what is suggested by the formula derived above by Rapoport.

Let us now consider the problem of the information as to the state of the visual field, as exemplified by successive states of the retina. We know that there is a bottleneck effect which operates between the retina and the representation of visual events in the cortex, possibly in area 17 in much the same way as they were originally at the retinal level. This bottleneck suggests lost information, and what is more important the method by which information is selected. The extent of the bottleneck as suggested by Polyak is that 10^8 photoreceptors map on to 10^6 ganglion cells, which implies a ratio of 100 to 1 on the average. This average covers a range of 1 to 1 at the fovea to many hundreds to one in the periphery of the retina. The reintegration of information at the end of a bottleneck is characteristic of the nervous system and depends on temporal summation.

Sir Henry Head's distinction between epicritic and protopathic vision and the nature of these connexions suggest that detailed vision of the cones presents no serious bottleneck which applies only to the protopathic or generalised visual states, recording only crude characteristics of change of brightness.

Rapoport's model does not consider the sort of problem that is raised by the distinction between epicritic and protopathic vision. He addresses himself rather to the general problem of transmission of information with minimal loss of information.

The system of minimising the loss of information involves the suitable choice of a code. The reader will have seen from our example of coding that the codes can be constructed for various purposes, and we should not construct one only which merely retains accuracy of detail. Rather we should want to take cognisance of the epicritic-protopathic distinction and construct two sorts of codes. One must retain detail and this will be easiest at the region of least bottleneck. The other must try and retain as much information as possible while maximum attention will be given to speed of signal, the recording of movement, and so on, for peripheral photoreceptors and great detail in the areas of maximum acuity.

This problem of the appropriate coding suggests the need for detailed anatomical knowledge, and in the lack of this we can construct neural or logical networks as models and consider what code should be used for systems that are nearer the known structure of the optical system.

Rapoport and Culbertson have suggested models that have a fair measure of realism and can be suitably coded to transmit information in the manner necessary to retain as much information as possible. The actual suggested codes and models are complex and cannot be reproduced here, although they are constructed in terms of the principles described.

We can illustrate briefly the sort of network that will reproduce the effect of a bottleneck and is thus an analogue of the nervous tissue in the optic tracts. The circles represent elements that can be fired by impulses passing down the fibres leading to the elements, and the element will itself fire if the inputs that fire simultaneously exceed the threshold number of the element, which is written as a real number inside the circle. Inhibitory input fibres are drawn with open circles and excitatory ones with closed triangles. Fig. 2 shows information passing through a bottleneck in a logical or neural network.

The bottleneck net of Fig. 2 shows that information will be lost since even if the proper order of firing is preserved, the distinction between the two input fibres will not be preserved.

We should next consider the relation between this outline of the visual system from an information-theory viewpoint and our general knowledge of the visual system.* There is some evidence that the lateral geniculate body plays the part of temporal summater in that the spatial pattern depicted on the retina having been transmitted through a constriction has now to be reassembled.

Osgood and Heyer, following Marshall and Talbot, have tried to account for certain distortions of the visual field, as well as the discrimination of different aspects of that field, such as the ability to discriminate two lines that are very close together. They have done this by considering the interaction of fatigue and excitation gradients at the level of the visual cortex. Such an explanation is not beyond possible criticism, although our lack of precise

* See F. H. George "Vision and Behaviour", DISCOVERY, 1957, vol. 18, No. 6, pp. 237–42.

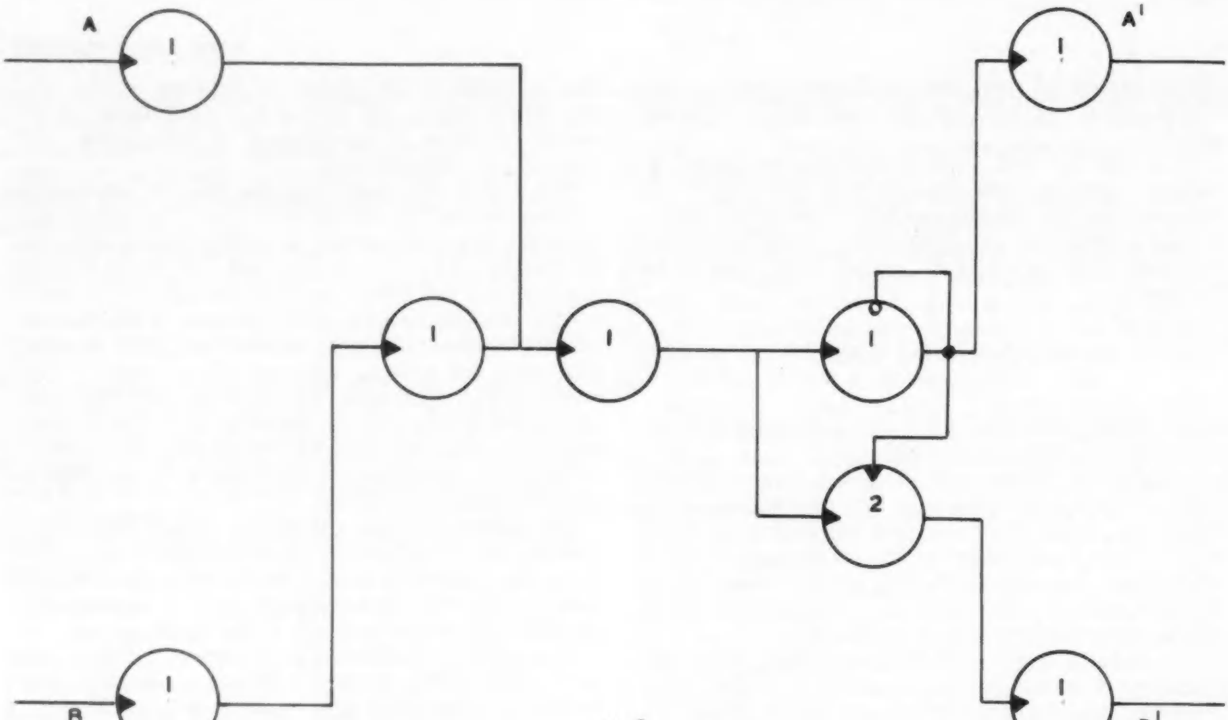


FIG. 2.

knowledge of neural activity at these levels reduces our discussion to guesses guided solely by questions of logic and internal consistency. Can we derive any help from information theory?

It is certainly possible that mere frequency of firing in a cortical area should convey information about maximal stimulation. There will be set up a ridge of excitation in the cortex under steady stimulation. This, if true, is novel from the point of view of information theory, since we don't usually say that in sending Morse when we send faster we mean to convey any special information. Yet if Osgood and Heyer are right, then the speed of impulses is part of the code itself, and the evidence from our knowledge of the auditory system suggests the truth of this. This now suggests that it might be a fundamental mistake to directly compare a code in the form of a language code with something like the visual system since it seems to work by a code founded on a pictorial basis, which suggest that the ridges of excitation occurring in the visual cortex have a topological relation with areas of excitation in the retina.

The above problem is not really very great, and serves as a reminder that information in the visual system will depend not only on the pulse—no-pulse relation (these are the only letters in the binary system used) but the information coding is a function of frequency of pulse to no-pulse, and possibly such things as ratio of pulse to no-pulse in a particular area of the visual cortex; this is precisely what Osgood and Heyer are suggesting.

Selfridge has suggested that for visual pattern recognition we need to be able to transform information derived from a primary image in terms of operations such as averaging and emphasising local differences in the visual field such as at contours, at corners of lines, and so on, but he includes the counting of 0's and 1's and this, if it is the method by which the visual system actually works, suggests that Osgood and Heyer's theory cannot be directly interpreted in information theory terms, since the process of recognition is very much more than the mere isolation of contour lines and involves the permanent memory store, a fact which is indeed obvious. We might therefore come to think that we cannot get a complete picture of coding for the visual system in terms of Osgood and Heyer's theory alone, and since this is the case, one can but wonder at the adequacy of their attempt to show how anything even as complicated as contour recognition can be isolated from the larger recognition activities of the visual system; surely there can be no wholly separate code for these different aspects of recognition. Information theory it will be argued is of use in that it suggests a new way of looking at the visual system and it suggests severe limitations on some of the models that have so far been used to try and construct predictive theories.

The great general value of the approach here discussed is that we have a method of analysing the information content and capacity of certain biological systems by the construction of easily defined models that can now be compared with actual biological systems. On the other hand models can be built in terms of networks such as that illustrated to indicate the nature of the bottleneck. This brings out the fundamental value of Cybernetics. It is a method of studying precise systems that can be made to approximate more and more closely to biological systems. This also allows the applications of mathematics to biology and this itself is of the utmost importance.

No space is available here to discuss the method of constructing the nets, but these have been described elsewhere in relatively simple fashion.*

* F. H. George, "Logical Nets and Behavior", *Bull math. Biophys.*, 1956.

FUNGI: FRIEND AND FOE

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The late Mr A. A. Pearson, twice President of the British Mycological Society, told the present writer that he had read in the *Journal* of the Swiss Mycological Society (December 1947) that a correspondent claimed to have cured very bad rheumatism by persistent eating of fungi. Some will have doubts about the authenticity of this claim, but it is well known that many fungi have medicinal virtues: extract from the highly poisonous red-capped fly-agaric (muscaridine) is used as a tincture against epilepsy and as an insecticide; ergotin, from ergot of rye, is very effective in stopping haemorrhages. Readers, however, would be well advised not to experiment with these drugs without the approval of a qualified physician.

Nowadays everyone has heard of how penicillin, the drug made from the fungus *Penicillium notatum*, prevents the growth of certain harmful bacteria, so that it is said to be an "antibiotic". It is not generally known, however, that several fungi of the toadstool type have similar bacteriostatic qualities. The most valuable of all fungi are certainly the life-savers, those that have produced the drugs penicillin, streptomycin, chloromycin, and aureomycin (extracted from a golden-yellow mould). These drugs halt the invasion of bacteria, prevent the spread of the disease, and so enable the patient to regain his health. Hundreds of species were tested during the last war and their juices were extracted and tried out, but although some reacted well they were eventually discarded as being not economically practical.

Many forest trees and plants on peaty soil cannot live without the assistance of a fungus. It attaches itself to the roots and forms the so-called mycorrhiza. The toadstools under trees are usually the fruiting bodies of these fungi. Both the fungus and the plant or tree seem to benefit by this association, which is therefore termed symbiotic. The fungus may get carbohydrates from the host plant and, in exchange, breaks down the organic matter of the soil into simple, soluble, organic compounds that the root is able to deal with. A great number of orchids cannot live without a mycorrhiza.

Eel-worm does millions of pounds' worth of damage to root crops every year. Efforts to check its ravages have been moderately successful by infecting the soil with predacious fungi (*Arthrobotrys robusta* and *Dactylaria gracilis*), which catch the worm in a constricting loop (something like a minute rabbit-snare) and devour it.

HARMFUL FUNGI

Who has not noticed a dead house-fly, apparently stuck to the window-pane and surrounded by what looked like a circle of fine white threads and powder? This is a familiar case of an animal killed by a fungus. A fungus similar in its habits also attacks ants, maybugs, beetles, wasps, spiders, and caterpillars. The vegetable growth may also sprout from the animal while it is still alive. We then have the unusual sight of a plant growing out of a living animal. Several spore-bearing branches may emerge from the same

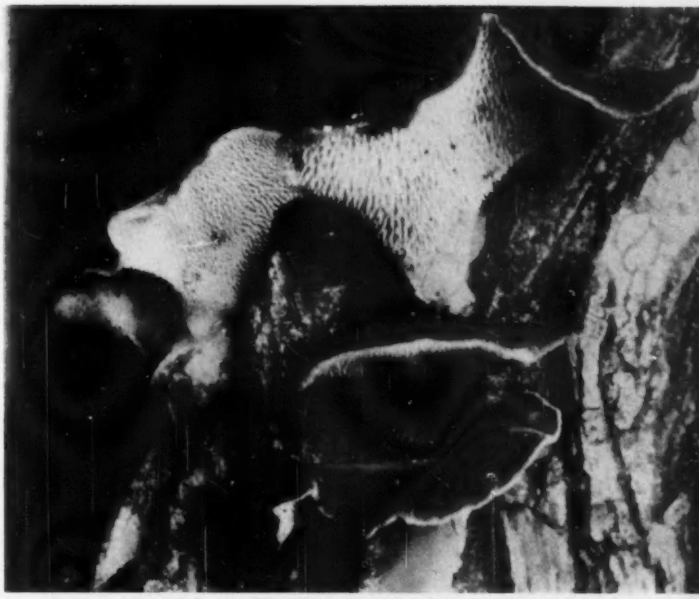
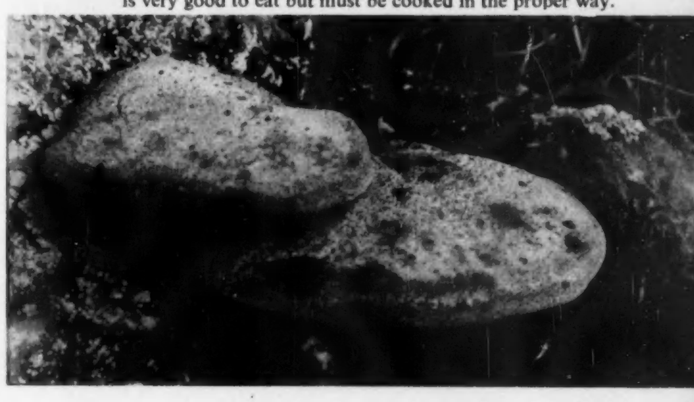


FIG. 1 (*above*). The "jelly hedgehog" fungus (*Tremelledon gelatinosum*), which is edible but not very plentiful.

FIG. 2 (*below*). The *Polyporus Schweinitzii* is a parasite which lives on pines and comes from the same group as the fungus which causes dry rot.

FIG. 3. The "beefsteak" fungus (*Fistulina hepatica*), which is very good to eat but must be cooked in the proper way.



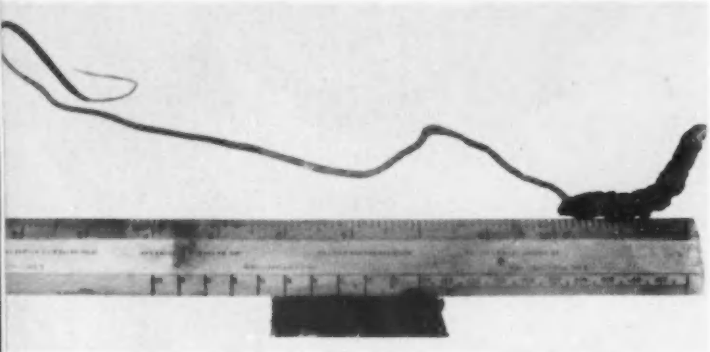


FIG. 4 (*above*). The vegetable caterpillar or ghost moth caterpillar (*Cordyceps Robertsii*), which is edible and is actually sold at the markets in Japan.

FIG. 5 (*below*). The Blewitts (*Tricholoma nudum*), which can be eaten but is rather indigestible.

FIG. 6. The lizard tuft fungus (*Leotia lubricata*), which is slimy to touch.

insect. One species of this fungus is called *Cordyceps militaris*, the red sporophores no doubt suggesting its specific name. In October and November they may be found, quite commonly, in wet grass near trees. In England they are usually from 2 to 3 in. high and ¼ in. broad. In New Zealand, those on the caterpillar of a ghost moth have been known to measure a foot or more.

Many diseases of plants, animals, and man are due to fungal infection. Dry rot is familiar to most people. It causes millions of pounds' worth of damage to timber, joists, and floor-boarding. During the war it spread considerably because ventilators had to be blocked on account of the blackout, and lack of ventilation is very conducive to its growth. Houses so affected in Germany before the war were condemned to be burnt down, so great was the danger of clouds of fine spore infecting other buildings.

The wilting of cress and the white mildew on shepherd's purse are the best-known examples of the harm done to many of our flowering plants through the agency of fungi. Tremendous losses are also brought about by rusts and moulds, especially among cereals, but we have probably noticed similar growths on our hollyhocks and antirrhinums. Potatoes, hops, vine, and most of the ordinary garden vegetables are liable to be attacked.

If one keeps goldfish or has a lily-pond in the garden, one can observe a frothy, soapy-looking scum that sometimes attacks the fish and soon causes their death. This, too, is a fungus, and the infected fish should be removed and sponged over with a mild disinfectant. Great mortality in silkworms, and consequently monetary loss, is caused by muscaridine, another fungal infection.

Man, being an animal, is not immune from attack, but, owing to his knowledge and intelligence, can take the necessary precautions to avoid trouble. Several skin diseases are of fungal origin, including what is known as athlete's foot, alopecia (where large clumps of hair fall from the scalp, leaving unsightly patches), and ringworm, in spite of its animal sound.

Hospital cases have been described of patients suffering from perforation of the bowel, due to abscesses along the alimentary canal, caused by the spore of a rust that had been sucked up with a soft drink by means of the old-fashioned unsterilised straw. Nowadays the straws supplied with milk to school-children are synthetic and made of sterilised waxed paper.

Out of the thousands of different fungi, only about forty are known to be poisonous; of these, only four or five are deadly. Those that emerge from a sort of socket or egg-shaped base should be avoided. Poisonous flowering plants are far more numerous.

One of our very poisonous toadstools, the red fly-agaric, can be eaten without fatal results when dried, but even so its after-effects are quite alarming. Some other poisonous fungi which are eaten with impunity in Russia and the Scandinavian countries are said to lose their poison when cooked.

CLASSIFICATION

The Agaricales is the name given to the familiar toadstools of our fields and woods.

Of these there are more than 1300 species (according to the latest computation by Pearson and Dennis), which are,

for the most part, shaped like the true mushroom and have reproductive spores attached to gills or blade-like outgrowths underneath the cap.

A rough classification of fungi may be made by considering the appearance of the spore-bearing layer, but for more exact identification we must take account of the colour, markings, and chemical reaction of the spore, and so forth. If the spores are found on sharp-pointed projections like teeth we have the Hydnum group. Sometimes the spores are in hollow pores, as in the Polyporous family, or in long tubes, as in the Bolets, or contained in little sacks or asci embedded in the surface, as in the Pezizas and others.

"EVOLUTION"

One can trace a sort of fanciful "evolution", or merging of forms, both in the Basidiomycetes, with spores exposed on club-shaped outgrowths, and in the Ascomycetes, with enclosed spores. Take, for instance, *Stereum hirsutum*, a tough, leathery fungus with a hairy upper surface, that may be found growing stemless on oak beams, logs, and palings. Its lower, or fruiting surface, is covered with minute club-shaped outgrowths (Basidia) bearing spores. Lengthen and sharpen these outgrowths and we get the characteristic appearance of the next group, the Hydnei, where the spores are borne on pointed teeth, closely resembling those of an india-rubber hairbrush. We can see such a fungus in Fig. 1. This is *Tremelledon gelatinosum*, of a gelatinous texture and rather diaphanous; sometimes with and sometimes without a stem; found in autumn growing from living trees, a few feet from the ground. It is popularly known as the "jelly hedgehog". A small species which is often overlooked is the "ear pick" (*Hydnum auriscalpium*), a name that is not at first self-explanatory in this 20th century, where the use of such an instrument seems to have died out. It has the shape of a small saltspoon, and is found on fir-cones. If the rows of teeth are now brought closely together, we get the Polypore; but if crowded together they form tubes and cylinders, as in the Bolets and some Polypores. *Polyporus Schweinitzii** (Fig. 2) is a near relative to dry rot, found growing at the base of pine-trees, a sure sign that they are nearing their end. The "vegetable beefsteak" (Fig. 3) is a good edible Polypore. It is found growing from the roots or lower trunk of oak-trees whose top branches are beginning to die off. It appears in August and September, and, when young and tender, is good eating if cut into thin slices and cooked slowly. Its flesh is extraordinarily like red meat, and the copious red juice it sheds adds to the illusion. A more beautiful, though poisonous, Polypore is *P. sulphureus*, which successfully attacks the very hard wood of old yew-trees. Its colour varies from canary to apricot, and its wavy outline and zoned body make it a conspicuous and handsome fungus. Now, if we imagine the tubes of these fungi to be unfurled and stretched out, we have the gills of the agarics. The Blewitts (*Tricholoma nudum*) (Fig. 5) are a common edible variety, but scarcely esculent. Their blue colour is apt to be upsetting, but they are quite harmless apart from being indigestible.

We can work out a similar case of "evolution" for the Ascomycetes, whose spores are produced in little sacks or

* Named after L. D. von Schweinitz (hence capital S for specific name).

FIG. 7 (*above*). The Jew's ear fungus (*Hirneola auricula judae*) can be used as an astringent.

FIG. 8 (*below*). Common morel (*Morchella esculenta*) is an edible fungus which appears in the spring.

FIG. 9. Fly agaric (*Amanita muscaria*) is a very poisonous fungus which was used for killing flies.

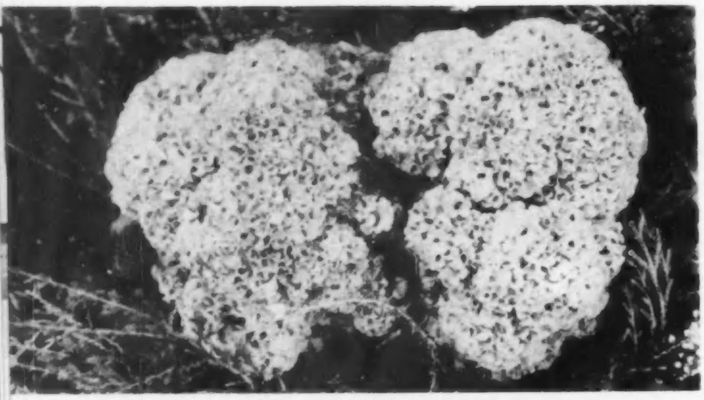


FIG. 10 (*above*). The "vegetable sponge" (*Sparassis crispa*). This fungus can be eaten when it is young.

FIG. 11 (*below*). Bush coral fungus (*Clavaria stricta*) is a rigid woodland species.

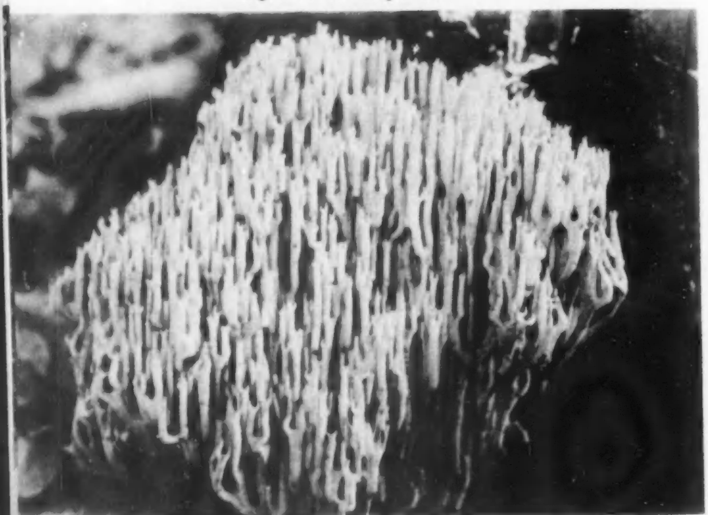


FIG. 12. "Bird's nest" fungus (*Cyathus striatus*), one of the most curious looking of all fungi.

asci embedded in the fruiting surface. If we start with the cup- or saucer-shaped group called Peziza, of which the elf cup is an attractive specimen, we find the fruiting-surface at the bottom of the concave part. If this were turned inside out by a force applied to the lower surface, we should have something not unlike *Leotia lubricata*, an olive-green, sticky fungus, some 2½ in. to 3 in. high with a small head. One might very well find it in pine woods in summer. Its English name is lizard tuft. A few minor irregularities at the top of this club-shaped fungus and we have the saddle-shaped cap of the Helvels, like *Helvella crispa*, found sometimes in meadows and sometimes under trees and hedges. Multiply these irregularities tenfold or more and we get the Morels (Fig. 8), found in similar habitats to the Helvels.

INTERESTING COMMON FUNGI

One of the jelly fungi known as Jew's ear (Fig. 7) is a really lifelike reproduction of a human ear: a reference, perhaps, to the ear of Malchus, cut off by Peter the Apostle, although one would suspect Malchus of being more Roman than Jew. It is quite a common fungus, and may be found in late summer and early autumn on logs and fallen branches of elm and elder. Another striking fungus is the "vegetable sponge" (*Sparassis crispa*) (Fig. 10); though edible, it is usually too crisp to be pleasant. It usually springs from the base of a pine-tree in autumn. The author has known it to reappear year after year in a school playground. Closely related to this is *Clavaria stricta* (Fig. 11), a very handsome bush-like growth found on a holly stump, but it is not so common. Lastly, we come to the very attractive "bird's nest" fungus (*Cyathus striatus*). It consists of shaggy deep cups containing a number of disc-like spore cases that look like eggs in a nest. *Crucibulum vulgare*, a smaller species, is not shaggy and has white "eggs" inside.

PRECAUTIONS

Sometimes mushrooms sold in shops have been gathered by children in the local countryside, or even by adults with insufficient knowledge. I should be chary of these. Very poisonous specimens may be found in the midst of a good crop of an edible variety. Often they are similar in their habitat and appearance to innocent types. There is no hard and fast rule as to "how to tell a mushroom from a toadstool". The fact that the cap peels easily is no criterion; many poisonous ones do the same. If a silver spoon turns black when held in a saucepan of cooking fungi, that is no reliable proof of the presence of poison. Change of colour when cut or bruised, pleasant or repulsive odour, are equally untrustworthy—the only safe way is to know and be able to recognise the characters of those you want to eat and those that are better avoided.

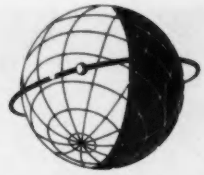
READING LIST

Ramsbottom, J., "Mushrooms and Toadstools", Collins.

Wakefield, E. M., "The Observer's Book of Common Fungi", Warne.

Swanton, E. W., "Fungi and How to Know Them", Methuen.

GEOPHYSICS AND SPACE RESEARCH



By ANGELA CROOME

FIG. 1. Throughout its stages the International Glaciological Expedition to Greenland has made the fullest use of helicopters. Here a helicopter team are placing ablation markers in a glacier during the summer of 1958.

Greenland Expedition Starts Main Work

This month (April) the main effort in the field of the International Glaciological Expedition to Greenland begins (DISCOVERY, January 1957, vol. 18, p. 31; and October 1957, vol. 18, p. 438). It will continue until September with about sixty men and some fifteen vehicles taking part, four aircraft and two helicopters will also be in use. The overall object of the expedition, which is being conducted co-operatively by scientists from Denmark, France, Germany, and Switzerland, under the leadership of M. Paul-Emile Victor, is to make a detailed study of the Greenland ice-sheet lying between 68° and 74° N and from coast to coast. The ice in this area is now known to be the most active.

As the volume of the inland ice is known and also the topography of the underlying rock, the main concern of the expedition will be with the dynamics of the glaciation. The following measurements are envisaged:

(1) *Movement of the central section.* The horizontal motion requires the placing of markers that will last ten years and a very careful determination of their original position. The previous work by French expeditions in this area has established that the annual rate of movement is about 150 m. a year; this gives a basis on which to work. Accordingly, it is planned to place markers at 10-km. intervals along a west–east profile 800 km. long. An accurate triangulation, using tellurometers, will link the west coast to the east and ensure that the position of the markers is known precisely. A re-measuring of the profile in a few years' will determine relative and absolute movements, and it will then be possible to work out the distribution of tensions.

Vertical motion will also be measured.

(2) *Variations of the marginal zones.* Photogrammetry of the western marginal zone of the inland ice between 68° and 74° N will be made. Similar coverage in a few years will show if there has been any climatic change.

(3) *Volume-discharge of the large glaciers.* Trials made during the expedition's reconnaissance work during 1957 have shown that it is possible to determine the superficial speeds of the great glaciers by taking aerial photographs of the fronts at several days' interval. If the thickness of the glacier is known, the volume discharge can be worked out from observing the number and area of icebergs that have "calved" in the period.

(4) *Accumulation* will be assessed by a number of methods.

(5) *Ablation* can be measured superficially on the markers. Studies of the drainage basins and thaw rivers in the ablation zone will also be made.

(5) *Mass budget and variations of the inland ice.* In addition to balancing accumulation and ablation, the underglacial thaw must be determined. This is to be done by studying the temperature profile and salinity of the great glacier fjord of Kandgerlugssuaq, on the west coast (71° 31′ N).

(6) There is also to be a programme of geophysics, including electric, seismic, and gravity soundings. Heavy explosions on the central ice-cap and along the edge of the ice-cover should reveal any deep faults that may exist.

The summer field-party's activities will be supplemented by that of a small wintering party at a central ice-cap station.

The IGEG is likely to prove the largest and most important international polar expedition ever mounted.

Weather Eye Opens

It is a telling tribute to the broad front on which American space programmes are proceeding that with the space age a bare eighteen months old it has already begun to be useful. This is perhaps the principal implication of the U.S. Navy's launching on February 17 of a satellite to monitor cloud-cover. It is particularly agreeable

to place this achievement to the credit of the so frequently ill-starred *Vanguard* project. The experiment was carried aloft by the first full-sized *Vanguard* satellite to go into orbit (the fourth such satellite to be launched). This launching went off without a hitch.

The experiment (the only one to be carried apart from an internal temperature check) was contained in a 20½-in. 21-lb. sphere which separated from the rocket's last stage, also now in orbit. Perigee was initially 335 miles above the Earth and apogee 2050 miles. It is expected that the satellite will be in orbit at least for several hundred years and possibly for ever. Its telemetry was only expected to last a fortnight and tracking beacon a month. The orbital path lies between 35° north and south of the Equator and the period was initially 126 minutes.

The Americans have long recognised the observation of cloud-cover as a short-cut to weather forecasting. Provided the clouds can be seen in sufficient perspective they present the weather-pattern in an admirably graphic form. Before the advent of rockets and satellites the difficulty has been to achieve the sufficient perspective. Recently the U.S. Office of Naval Research has been firing rockets up to 90 miles on the American Atlantic coast in order to photograph cloud formations indicating the possible approach of hurricanes as much as 700 miles out to sea. Such rocket observations inevitably can only yield "spot" readings; a satellite can provide a continuous monitoring service.

The technique tested in the limited payload of *Vanguard II* was not unlike that designed for studying the hidden face of the Moon in the first American lunar probes. Two photoelectric cells were mounted behind windows on each side of the orbiting sphere which is spin-stabilised round the axis of forward motion at the point of reaching orbital velocity. This means that for most of its orbit each cell in turn scanned a swathe beneath it in terms of relative lights and darks. Cloud-cover can be distinguished from land and sea because it has a greater reflectivity than either. About a quarter of the globe, the region of the Tropics, lay within the field of view of the satellite's photoelectric eye. It is estimated that a band of the Earth's surface about 600 miles long and 7 miles wide was "swept" with each revolution of the satellite. Relative reflectivity was recorded on the tape of a miniature automatic tape-recorder as a series of pulses suitable for telemetry. Solar cells behind the satelite's windows automatically switched off the tape when the satellite crossed to the dark side of the globe and vice versa.

Once in each circuit of the Earth, one of five specially equipped ground-stations contacted the satellite by radio and received the tape playback for that orbit. About 60 minutes of taped material took 60 seconds to transmit. The "picket fence" of receiving stations were at Fort Stewart, Georgia; San Diego, Southern California; Lima, Peru; Antofagasta, Chile; Santiago, Argentina; and Woomera, Australia (where special equipment for this purpose has recently been installed). The recorded data was then sent on to the U.S. Army Signal Corps' research laboratories at Fort Monmouth, New Jersey, where it was electronically processed to turn it back into crude pictures. The 40-ft. film strips of each circuit are then fitted together in the manner of an aerial survey photo-mosaic to form a cloud map of the equatorial regions.

Though these preliminary observations must be reckoned rather crude, American meteorologists are confident that they will enable an extension of the present 30-day forecasts to 90 days. The introduction of a television scanner, a longer battery-life, and a pole-to-pole orbit will substantially improve results.

Lazarev Station Set Up

The Soviet expedition ship *Ob* reached the Princess Astrid coast of Dronning Maud Land on February 9. The setting up of the new station called Lazarev, after the famous Russian navigator Mikhail Lazarev, began on February 14. The position chosen was on a projecting shelf glacier at 69° 56′ S, 12° 58′ E. The station is about half a mile from the edge of a shelf tongue that projects into a vast bay formed by the coast and projecting shelves. The *Ob* broke out a dock for herself to unload on to the coastal ice about four miles from the station site. About 900 tons of equipment has gone ashore for the station. A colony of Emperor penguins has been discovered in the neighbourhood of Lazarev.

A wintering party of six men is to remain at Lazarev. Meteorological, aerological, actinometric, glaciological, and geographic observations are scheduled. One of the first undertakings after the landing was for a small party of scientists under Prof. Mikhail Ravich to fly to the Voldat mountain range in the immediate interior and to set about surveying a route for the descent of next year's continental traverse expedition to the coast. The Voldat range is expected to be one of the severest obstacles in the path of the projected Russian tractor trek. The range, which centres on 71° 30′ S, 11° 30′ E, is one of the most precipitous in Antarctica. It was discovered from the air by the German 1938–9 Antarctica expedition but has never been reconnoitred from the ground. To complete their plan and reach their destination at Lazarev the Russians must succeed in crossing or outflanking the range.

Landing on Oates Land at Last

The Australian Antarctic expedition under Mr Phillip Law succeeded in making the first recorded landing on the coast of Oates Land in mid-February from the expedition ship *Magga Dan*. Three previous attempts since 1948 have been frustrated by pack-ice. *Magga Dan* was in fact stuck for some time this year but succeeded in freeing herself. An aerial reconnaissance was made and the Australian flag planted by the landing-party on an 800-ft. peak.

American Space Plans: Rockets Galore

Thirty earth satellites and space probes are scheduled for the immediate future by the U.S. space agency, NASA. They will be spread equally over this year and 1960. In addition, some forty sounding rockets are planned for 1959 and about a hundred for 1960. NASA has asked Congress to increase the appropriation to $500 million for these and related space schemes for the current fiscal year. "This is the last time that, in the foreseeable future, NASA will be requesting a budget of only half a billion dollars," commented Dr Keith Glennan, Administrator of NASA, in his testimony before the Senate committee on Aeronautics and Space Sciences in February.

The programme of thirty space vehicles represents the flowering of the "first generation" space experiments. The "second generation" programme, which includes advanced meteorological and communications devices and the launching of an astronomical telescope into space must wait on the programme of development of large booster rockets now being put in hand. This programme will cost in excess of $2000 million. These rockets will enable the larger payloads required for the more ambitious experiments to be carried into space. It is hoped to launch the first of the second generation experiments in 1960. $200 million alone is earmarked for the development of a large rocket engine capable of producing 1 to 1½ million pounds thrust. This will be capable of flinging many tons of payload into space, it is claimed. A single firing of this giant booster will cost $20 million, it is estimated.

Another $200 million is being spent on project Mercury, the project for launching a man into orbit, the trials of which are expected to start very soon.

In his testimony, Dr Glennan gave a hint that co-operation on experiment designs from scientists abroad is already being sought by his agency through

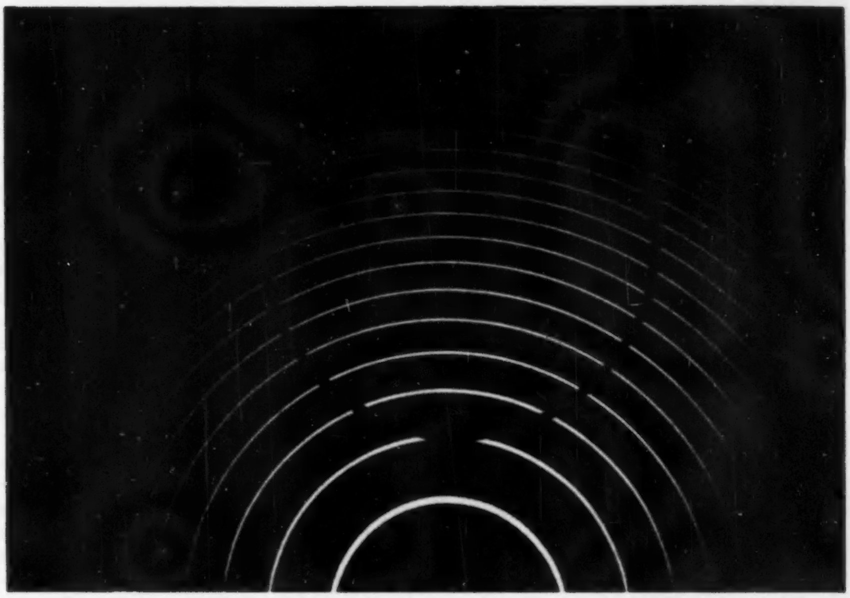


FIG. 2. Interferometer pattern from single isotope mercury vapour lamp.

COSPAR. The second meeting of this body took place at the Hague on March 12–14.

Eclipse

The object of the complex eclipse experiment mounted by Dr H. von Klüber of the Cambridge Observatories on the atoll of Atafu in the South Pacific on October 12 was to measure the temperature of the Sun's corona, using an interferometer technique, (DISCOVERY, 1957, vol. 18, p. 122). The Atafu party was fortunate in having clear skies overhead during the period of totality, and excellent results were obtained.

Only at the time of a total solar eclipse can more than the very innermost part of the Sun's corona or outer atmosphere be photographed. We know that the gas of which it is composed is highly ionised, and is at the same time exceedingly tenuous, and only because at the eclipse we look right through millions of miles of it does it become visible at all. The temperature at the Sun's visible surface is around 6000°K, but is very much higher in the inner corona, where it is of the order of one to two million degrees. The reason for this high temperature in the corona is not yet sufficiently known and is much disputed. Exact temperature measurements can be made during a total eclipse by measuring the widths of the lines in the coronal spectrum, using an interferometer. Fig. 3 is Dr von Klüber's eclipse photograph of the corona, in the light of the famous green line (of iron) at wavelength 5303 Å, with the interference fringes superposed. For calibration purposes a special lamp containing a single isotope of mercury, prepared by Harwell, was used (Fig. 2).

Photographs were also taken during this eclipse using a different spectral line, the well-known red line, also of iron, at 6374 Å. The exposures for both lines were between 20 and 60 seconds Measurement of the plates and the derivation of the corona temperature will require some months.

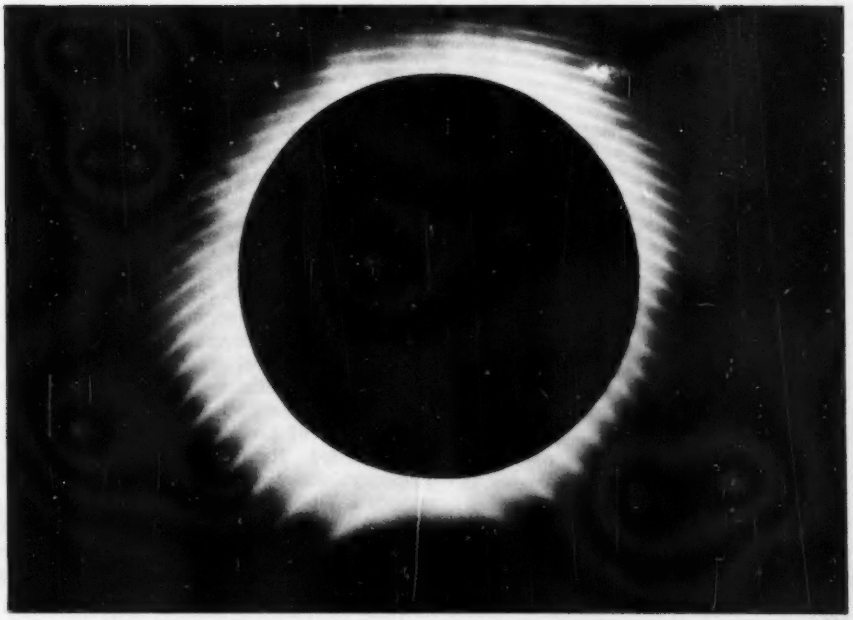
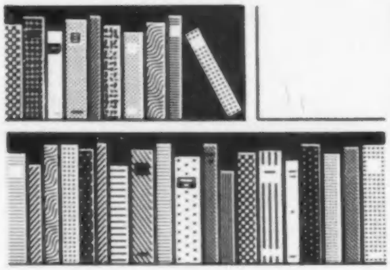


FIG. 3. Eclipse plate.



THE BOOKSHELF

Rheology: Theory and Applications, Vol. 2

Edited by Frederick R. Eirich (*New York, Academic Press, Inc.; London, Academic Books Ltd, 1958; xiii+591 pp., $18*)

In his preface to vol. 2, the editor has discussed three criticisms made by reviewers of the first volume: "overlap and repetition, unequal approach or even conflicting views and non-uniformity of nomenclature."

No doubt there will be differences of opinion on the first point. The editor's aim has been to produce a comprehensive book so that readers will not have to seek information elsewhere. Yet this book is clearly intended for those with a considerable rheological background, and one wonders how many of them do not already have other textbooks on their shelves. For example, R. Meredith's chapter on "Fibres" is little more than a 50-page abstract of his admirable book on the same subject, published only two years ago and, it is hoped, widely read.

Your reviewer finds little to complain about under the second heading; all the chapters in this volume set a high standard and the authors' differences of outlook would seem to be in no way disconcerting. Though it is good to learn that at least some unification of symbols and nomenclature may be expected in vol. 3, it is still felt that, in spite of difficulties, at least the most widely used symbols might have been standardised in the earlier volumes. Such criticisms would not have been worth making had the book not been of the first importance. But, whatever minor faults one may find, there can be no doubt of the significance of this monumental work.

The present volume has seven chapters mainly concerned with theoretical treatment of high polymers, a very complete chapter on gelatin, a shorter and less original essay on asphalt, and a fascinating account of somewhat speculative rheological studies on the Earth's crust and interior.

The last three chapters are concerned with experimental techniques: Chapter 11 deals mainly with sinusoidal stressing, Chapter 12 recapitulates the fundamental theories of capillary and concentric cylinder viscometers; and Chapter 13, the most useful of the three, is concerned with goniometric methods, Weissenberg effects, and "crazing".

The production of the book is excellent, the price is high, and the misprints are few.

G. W. SCOTT BLAIR

Productivity and Social Organisation: the Ahmedabad Experiment

Technical Innovation, Work Organisation and Management. By A. K. Rice (*Tavistock Publications Ltd, xiii+298 pp., 35s.*)

This study describes a programme of operational research undertaken by the author in his capacity as a consultant from the Tavistock Institute of Human Relations with an Indian textile manufacturing company. The starting-point is the assumption, now usually taken for granted, but none the less only recently validated in the science of human relations, that any system of production is a socio-technical system; that production requires a *technical* organisation and also a *work* organisation, relating the workers to each other. The setting of this investigation is important: on the one hand, the Company, among the most progressive in the sub-continent: on the other hand, a complex of differences in tradition, language, caste, religion, and politics, all diversely affecting the operations of industry. It is relevant that social *mores*—for example, the fact that whereas thousands of workers were accustomed to sleep in the streets at night, but were hardly able to do so by day—constituted a powerful obstacle to the introduction of the three-shift system. Again though trade unionism in India has far to go, the city of Ahmedabad is exceptional, as the centre of the well-organised Textile Labour Association: its traditions, inherited from Gandhi, make it responsible in negotiation if conservative in reaction to technical change. We must expect to encounter such problems in adaptation in many under-developed areas.

Mr Rice undertook three main ventures in operational research for the Company. After initial disappointments, he successfully reorganised automatic weaving: in place of an earlier aggregate of individuals with confused tasks and job-relationships, workers were regrouped into small work-groups, internally structured and led. The effect on morale and efficiency was marked. Further, he essayed a similar reorganisation of non-automatic weaving. Despite a more tradition-bound atmosphere (a campaign against rationalisation supervened), job-study and personnel regrouping evoked considerable enthusiasm, producing tangible results. He also submitted a basic reappraisal of the management-structure, involving an examination of the chain of authority and the creation of new departments and control methods. There is highlighted in this process the problem of transition from the traditional Indian family concern of management-agents to a more broadly based professional staff.

Although not an easy book for any but the management specialist, the Ahmedabad Experiment deserves to be widely read for it vindicates convincingly the practical value of operational research. It is, however, a pity that Mr Rice was not able to provide fuller data as to the overall financial advantages of his changes, although considerations of commercial security seem to have been a factor.

Discordance between social traditions and mechanisation, of which this study treats, may be noticeably marked in India, but in our more advanced society, where the pace of technical change is rapid, tensions are bound to appear too. It is the task of operational research to diagnose and prescribe for these. The author poses the challenge in his concluding words: "A start has been made. It remains to discover whether continuous and controlled adaptation to change can become so much a part of the new organisations that the hectic pace of the past three and a half years can itself become an accepted and acceptable tradition."

D. GINSBURG

Antisera, Toxoids, Vaccines and Tuberculins in Prophylaxis and Treatment

By Dr H. J. Parish (*Edinburgh, E. & S. Livingstone Ltd, 4th ed. 1958, x+25 pp., 30s.*)

Dr H. J. Parish's book has now reached its fourth edition and has grown from 168 pages of Crown 8vo to 256 pages of Demy 8vo, and in so doing has lost the first phrase of its originally long and complicated title, for "Bacterial and Virus Diseases" has disappeared. Perhaps if the present-day passion for coded initials continues the next edition of this book may be called "Ser./Vac./Par."

Of the smaller and more specialised textbooks this is a very valuable example not only because it gathers together a great deal of information not otherwise available in one book, but because it is

in its own right an extremely well written and useful volume. Four introductory chapters, concisely and clearly presented, deal briefly, but adequately, with the general problems of theory, use and methods. The rest of the book is divided into three sections (*a*) dealing with antisera, including antitoxins, anti-venom, etc.; (*b*) bacterial vaccines and toxoids and also tuberculin; and (*c*) the viral vaccines, including a short and up-to-date chapter on poliomyelitis vaccine.

Finally, there is a dated historical survey of most of the diseases covered. This survey is perhaps the weakest feature of this book, and can be called patchy, at best.

The book is well produced and illustrated, though one or two of the coloured illustrations might be considered remarkable rather than useful. It is a pity that the Bibliography is not rather more extensive, but it is hoped that the next edition may see an improvement in this and thus bring it up to the standard of the rest of the book.

In general, the book presents a clear and critical account of the use of vaccines and sera in medicine giving detailed accounts of dosage and procedure. The section on virus vaccines has been considerably extended in this edition and now includes good chapters on smallpox and poliomyelitis and an adequate one on rabies and yellow fever. Other virus diseases are grouped together in a slight chapter that is hardly adequate—measles is allowed three lines, but it is hard to see what can be left out if the present small convenient size is to be retained, unless the perhaps bitter truth be faced that diphtheria is no longer worth twenty pages.

A. F. B. STANDFAST

The Ecology of Invasions by Animals and Plants

By Charles S. Elton (*Methuen & Co. Ltd, 1958, 181 pp., 30s.*)

This is a book which has been developed out of a series of three talks broadcast in the Third Programme, and it has both the merits and the defects of that approach: the fluent colloquial style is usually a pleasure to read, though it does perhaps jar in places, but the subject-matter seems rather loosely put together and there is a tendency to digress. It is lavishly illustrated with 50 figures in the text and as many plates, many of them excellent photographs but not always really relevant, and this must have contributed to the somewhat high price. But there is no doubt that it will be a useful book as it contains a concise and well-documented review of what is an interesting and economically important branch of ecology.

The important idea that is put across is the explosive nature of most successful invasions. The newcomer establishes itself in a small area, sometimes rather slowly as it becomes adjusted by natural selection to the new environment, and it then bursts out rapidly and widely, enjoying over its native competitors the great advantage that it will usually have left behind most of the natural checks to its increase, in the way of specific diseases and predators. When it has filled the whole of the available new habitat, density-dependent factors begin to operate to limit its further increase, and there may even be a regression, until finally the new species settles down as a permanent inhabitant of an environment which itself must become adjusted biologically to the invader. This process of adjustment usually involves eliminating the previous occupants, either forcing them into a restricted and specialised niche where they can still compete with the newcomer, or else resulting in their complete extinction.

Mr Elton emphasises that nowadays Man is much the most important agent in distributing animals and plants around the world, and that these deliberate or accidental introductions can start off many successful invasions which significantly alter the natural fauna and flora of different regions. It is suggested that this must in the end lead to a more uniform distribution of species and to a loss of the present distinctions between the different zoogeographical realms. But actually the invasions for which Man can be blamed involve only a tiny fraction of the total of living creatures, and a successful invasion is relatively a very rare event. Moreover the dangers are now well enough understood so that the deliberate introduction of larger animals, which cannot be carried unintentionally, will probably be stopped. Unfortunately that will not save many more fine animals and plants from extinction, for they are directly threatened by the most rapacious of all invaders, which is Man himself.

C. B. GOODHART

Atlas of the Sky

By Vincent de Callatay. Translated and with a Preface by Sir Harold Spencer Jones, K.B.E., F.R.S., formerly Astronomer Royal (*London, Macmillan & Co., Ltd, 1958, 160 pp., 5s. net*)

This work was originally published in French under the title "Atlas du Ciel", by Les Editions de Visscher, Brussels, and its author was awarded the Prix Edouard Mailly by the Academie royale de Belgique (Classe des Sciences) in February 1956 on the occasion of the publication of the original Belgian edition of this Atlas. Sir Harold Spencer Jones's preface provides a very short summary of the developments in astronomy from the remotest times up to recent periods, and this is followed by the author's introduction which gives the reason for the publication of the Atlas and also supplies a description of the maps and of the textual matter.

In the 36 plates the stars are shown as white spots on a dark background—in other words, the heavens are represented as we see them—and of these plates 9 are planispheres showing the sky as seen from various latitudes, and the remaining 27 plates show more detail, each one depicting a portion of the sky. One-third of these 27 plates covers each of the portions which include the northern hemisphere, the equatorial regions, and the southern hemisphere. Those who study these excellent maps will have no difficulty in seeing the connexion between them because each plate overlaps neighbouring plates. In some cases there has been a little displacement of the centres, the object being to bring the principal constellations into central positions on the plates.

In addition to these plates there are 45 complementary maps on which each of the 88 constellations is shown with their names and boundaries, and short notes draw attention to the principal objects of interest on the maps. A very useful Alphabetical Table of the Constellations is given on pp. 18–19 and provides the Latin and English names and also the numbers of the plates on which they can be found as well as the pages of complementary charts. One example explaining how this arrangement assists those who are studying the constellations and their stars and also any special objects in the constellations follows:

The Table gives Canis Major and in the next column its English name, The Great Dog, which is followed by Plates 26–29 and in the last column readers are referred to p. 120 for Complementary Charts. On turning to p. 120 they find a map of this region and also short descriptions of interesting objects, such as Sirius, the open cluster M41, etc. Those who make use of this Atlas will find it invaluable for studying stars whose brightness is equal or superior to the 5th magnitude, and they should bear in mind the rule given on p. 14, that the first magnitude has been assigned to all stars brighter than 1·5 magnitude, the second magnitude to those between 1·5 and 2·5 magnitude, etc. At the end of the book there are 12 photographs showing a number of well-known objects such as open and globular clusters, extragalactic and planetary nebulae, photographed at Mount Wilson and Palomar Observatories.

M. DAVIDSON

The Scientific Background

By A. Norman Jeffares and M. Bryan Davies (*Sir Isaac Pitman & Sons Ltd, 1958, xii+306 pp., 21s.*)

Those of us who are in the sixth form, or who would like to return there and make a better job of it, will enjoy this book, the title of which is misleading. The authors, exponents both of English literature, have bravely and forthrightly, in the manner of the Dutch making a *polder*, made an anthology of good prose, much of it by scientists and much of it about science. Their selection shows that scientists can and frequently do, write clearly and beautifully when they feel like it (or are broadcasting) and that for those of us who "did arts" there can be as much enjoyment in reading a scientist in a communicative mood as there is in reading any other good model. Some scientific paragraphs by unscientific people like Lady Mary Wortley Montagu (on smallpox), Sir Walter Scott (on polio), and the gentleman who climbed the turret of King's College Chapel, Cambridge (on how to do it), are examples of clear writing, and there is some good advice from Benjamin Franklin and from Dean Swift on the English language as a precise instrument.

Some would have preferred a chronological order. Others might have liked the book divided by subject. On the whole, however, the authors lead us skilfully from paragraph to paragraph, along a thread of their own, one end of which they put into the reader's hand in their introductory chapter. Those using the book for teaching purposes would feel free to make use of or to discard this thread.

A fresh and catholic selection, the compilers' choice ranges from Michael Faraday (why did no one introduce us to him at school, where we met so many less attractive characters?) and Gilbert White to Eddington, Hinshelwood, Coulson, and Blackett. The inclusion of Tacitus in translation might be considered unfair, and perhaps also the Army Order of 1918 which said "Further information as to the scope of aeroplane reconnaissance in connexion with your operation will be sent you shortly." Some of us might have liked to see a little of Francis Bacon's own writing (as well as John Aubrey's description of his death, which is given), and perhaps a bit of Humphry Davy and of Joseph Black and possibly a little less of Jeremy Bentham and Adam Smith.

There are one or two points of misarrangement. Count Rumford's biography might be attached to the first and not to the second extract from his work. This applies also to what is said about Charles Darwin. Perhaps Stephen Hales should be described as a clergyman.

The book ends with a questionnaire which scientists and arts-men, having by now lost their inhibitions, may do together, and the authors' probably wise decision not to provide an index makes it difficult to cheat. MARJORIE LINSTEAD

The Tao of Science

By R. G. H. Siu (*Chapman and Hall, 80 pp., 34s.*)

The Western way of life is founded on applied science. It has its valiant defenders. But the boldest will hardly claim that it has at last given the answer to life's problems. If juvenile delinquency and the road-accident rate do not daunt the defender of the technological faith, he has still to face embarrassments such as a European glut in coal, and a global surfeit of H-bomb tests.

So it is refreshing to find a scientist who blends his practical experience, of organising research in America, with a point of view stemming from a very different culture. Dr R. G. H. Siu's "The Tao of Science" seeks to harmonise the way of Western science with another, taught in China two and a half millennia ago.

The character 道, *tao*, represents "a head" (首) and "advancing" (辶). *Tao* (rhyming with *now*) means "way" or "road". The single work attributed to Lao Tze, the exponent of Taoism, is known as *Tao Te Ching*—"The Way of Virtue Classic". Its opening sentence—surely confirming Lao Tze's right to his title, Old Master—may be translated: "The way that can be described is not the true way." Clearly, if we cannot define the subject of discussion, there cannot be contention about it. Without contention, harmony can prevail, and the follower of Lao Tze sees the keeping of harmonious relations between people and things as the greatest virtue. (Taoism later became associated with magical mumbo-jumbo. This is no more fundamental to it than is, say, extreme sabbatarianism to Christianity.)

Future generations will probably be surprised at the lack of understanding, by the now dominant Western cultures, of philosophies outside their own racial confines. The *Tao Te Ching* has probably influenced as many people as has the Christian Bible. Yet how many Europeans have read its five thousand words?

The strange imbalance will no doubt be slowly set right, and "The Tao of Science" helps such a trend. It may be taken as "required reading", not only by the practising scientist, but also by every executive in industry and commerce. Its author, now Technical Director of the U.S. Army Quartermaster Corps, has been Research Fellow in the Pineapple Research Institute, and chemist with the U.S. Department of Agriculture. His vigorous American style is tempered with a native grace and shrewdness.

Dr Siu's first part looks at the "Perspective of Scientific Progress". He opens:

> "A tiny fork of light was photographed in January 1939, in a cloistered German laboratory. Within the short span of six and a half years, the joint efforts of two other nations parleyed this innocent observation into the most awesome weapon of death. . . . And scarcely ten years later . . . intercontinental missiles thousands of times more devastating, were in the offing."

His perspective displays the historical causes which underlie his conclusion—that "Science speeds on unabashed!"

From this analysis he investigates "Effectiveness and Limitations of the Scientific Method". Appreciating the enormous advances made by scientific research, derived from the scientist's readiness to rely only on direct sense data, Dr Siu notes the penalty: a certain rigidity of mental outlook. "Fundamentally, scientists are causationists." We are here confronted with philosophies which take a less committed view, and our unprejudiced analysis is invited. The Hindus, for example, treated the question of causality differently, by regarding cause and effect as the same thing, seen from different vantage-points.

This more fluid approach introduces the third part of the discussion: "Injection of an Oriental Outlook." Dr Siu points out that an unremitting attachment to reason and logic involves the scientist in some contradiction. He must have faith in the existence of the unknown, else he would not investigate it. And faith is not reason. Thus he discusses the Eastern concept of "No-Knowledge", known in Chinese as *Wu* (無). Chuang-tze, the Taoist master, relates how the Spirit of the Ocean spoke to the Spirit of the River: "You cannot speak of 'ocean' to a well-frog—the creature of a narrower sphere . . . [only when you] have seen the great ocean, you know your own insignificance and I can speak to you of great principles." Dr Siu gives us a glimpse of the ocean. The reviewer can say no more.

In the fourth part, "Management and Practice of Modern Science and Research", it is engaging to see practical advice emerging from a seeming other-worldly point of view. It is noted that executives should recognise their own limitations and not assume, for example, that their sympathy for research means that they can do it. ". . . that a person enjoys eggs does not mean that he can lay one."

"The Assimilation of Modern Science" is the theme of the last part. Previous deliberations are distilled, in discussing

the philosopher executive. If we are to double-distil Dr Siu, his requirement of "human-heartedness" seems fundamental. The philosopher executive must be ready to leave behind the "divided outlook on life", stemming from complacency with the success of the specialists. For it is suggested that the very richness and diversity of science, the multiplicity of niches in which the research worker's ego may flower, can be its undoing. Science has need of those ready to leave

> "the intellectual throne for the life of a commoner. . . . When Christ asked the rich man to give what he had to the poor, he was not thinking particularly about the poor. It was the rich man who, choked in his plenitude of physical wealth, was in need of help. To soothe and guide science in her difficult yet inevitable decision will be the principal aesthetic contribution of the scientific leaders of today."

Science tends to take a point of view differing from that of Lao Tze: a way, or anything else, which cannot be described does not have relevant existence. May it be fruitful for science now to consider a sphere of knowledge with other premises? And if the scientist objects that he has no time for absurd contradictions, how does he accommodate the fact that atoms are being split daily, and that the Greek-derived word "atom" signifies that which cannot be split?

True we have grown up and left school. But does that mean that our education is finished?

G. BELL

The Drama of the Atom

By Werner Braunbek (*Oliver and Boyd, 1958, 242 pp., 15s.*)

This is an excellent book, written by a physicist for readers with no scientific training but who are interested to learn how a reactor works and an A-bomb is produced. It could perhaps be compared with O. R. Frisch's lucid lecture, "How it all began", at the Institute of Physics, in this case expanded to the full length of a 250-page book. It began in 1896 and the story is not yet finished.

The book has two serious faults. In a book of this kind it is essential to have a name- and subject-index. It has neither. A more serious criticism is of the translation: had the publishers spent a little on obtaining the help of a physicist to look through the translation, mis-spelling of names, and inaccurate scientific expressions could easily have been eliminated.

Translated from the German, the book is approximately 80% objective and 20% biased. Unfortunately, this 20% is permeated with a "pity the poor Germans" attitude. In the last 20 pages readers should not overlook the author's strong national prejudice. Apart from this, the bulk of the book is clear and one of the best of its kind.

P. ROSBAUD

Control

Edited by Christopher Rivington (*London, Rowse Muir Publications Ltd, monthly, 3s. 6d.*)

The existence of this new periodical was prompted by the emergence of control engineering as an important and fairly recent branch of technology. In the first issue, which appeared in July 1958, C. M. Burrell and J. K. Lubbock of Cambridge explain the fundamentals of automation control and discuss its development in an article entitled "What is Control Engineering?" The first issue also contains the following articles: "Electronic Systems for Industrial Measurement and Control", by M. V. Needham; "Dynamics of Mechano-Pneumatic Systems", by J. E. Samson; "Computer Control of Machine Tools", by T. N. Williamson; and "An Elementary Survey of Digital Codes", by G. C. Tootill.

SCIENCE ON THE SCREEN

Sunrise Science on U.S. T.V.

Courses in physics, sociology, history, and literature is being offered by WCBS-TV and New York University during the 1959 spring term of "Sunrise Semester", the early-morning educational television programme.

The four courses, any of which may be taken for either degree or certificate credit, are being given from February 2 until May 16. "Sunrise Semester" is presented six hours a week, Monday to Friday from 6.30 to 7.30 a.m. and on Saturday from 7 to 8 a.m. Its curriculum for the current term consists of courses in classical civilisation, mathematics, government, and literature.

The four spring courses, the professors who will teach them, and their schedules are:

History H1: a History of Western Civilisation, Associate Prof. Henry H. B. Noss, Monday, Wednesday, and Friday from 6.30 to 7 a.m.

Physical Science N1: The Nature of Matter, Associate Prof. Edgar N. Grisewood, Monday, Wednesday, and Friday from 7 to 7.30 a.m.

English H6: Literary Heritage II, Associate Prof. David H. Greene, Tuesday and Thursday from 6.30 to 7 a.m., and Saturday from 7 to 7.30 a.m.

Sociology S1: Man and Society, Prof. Joseph Bram, Tuesday and Thursday from 7 to 7.30 a.m. and Saturday from 7.30 to 8 a.m.

The courses, each of which carries three degree credits, are part of the basic requirements of the Programme of Co-ordinated Liberal Studies of NYU's Washington Square College of Arts and Science. They will be offered to viewers under the supervision of Dean Thomas Clark Pollock of Washington Square College. People who enrol for degree credit must meet the college's entrance requirements.

In addition to the home television lectures, NYU will offer periodic discussion sessions for each of the four courses at its Washington Square Centre and in three suburban communities: Garden City on Long Island; Montclair, New Jersey; and White Plains in Westchester County. These will be led by the course professors or their departmental colleagues.

Dean Pollock has described the discussion as "valuable supplements" to the video lecture-demonstrations. During the autumn term such sessions are being held for two of the four courses.

"Sunrise Semester" students may consult with their instructors during designated hours, either by phone or in the instructors' offices. In addition, the library facilities of the university are available to them.

Degree students will pay an overall enrolment fee of about £30 for each course. This includes a £2 non-refundable application charge, tuition, the cost of registration materials, and examination fees.

The courses will be produced for television under the supervision of Warren A. Kraetzer, Director of NYU's Office of Radio-Television. WCBS-TV (Channel 2) is seen within a 75-mile radius of New York City.

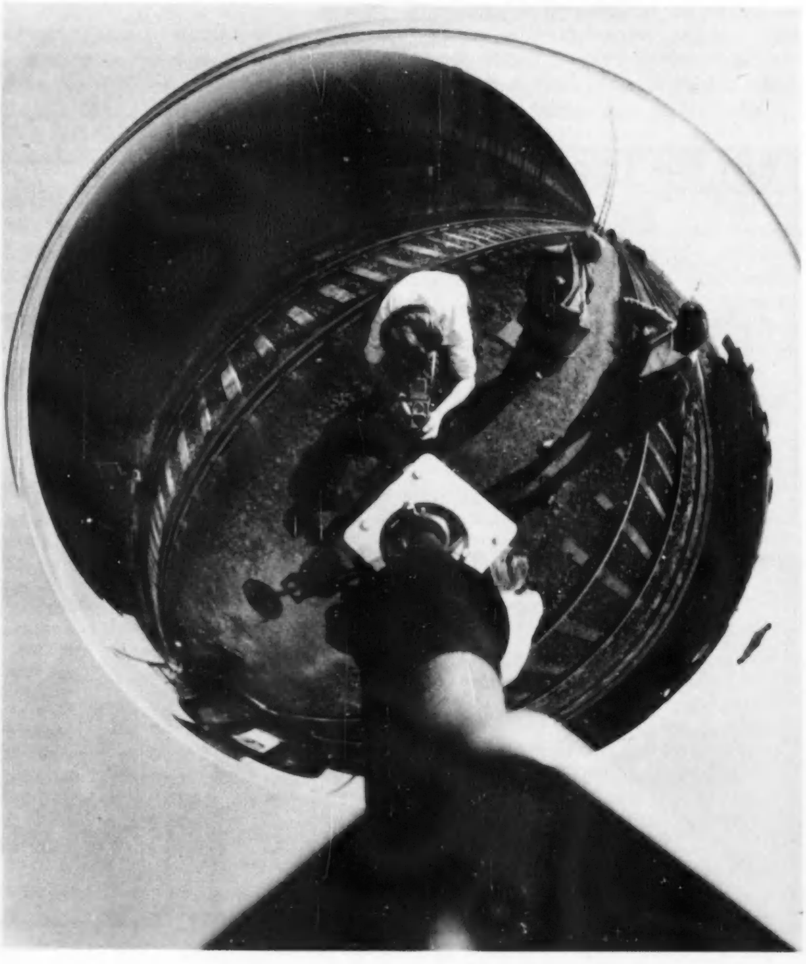
Samba in the Air—A Film Case History

"Samba 8 Ala Rotante", directed by Ugo Giacomazzi, sponsored by the Secretary-General of the Italian Ministry of Aviation, and technical consultant Colonel Pilota Ebbano Ghiglia of the Italian Air force.

This is a beautiful, exciting colour film on helicopters. As a documentary it is exciting and stimulating. In fact it is more than that, it is a valuable case history in film planning and film impact. Colonel Greco of the Italian Air Force was one of the participants at a series of courses on audio-visual aids for the Italian Productivity Centre in Rome, and he showed the film as an example of film utilisation.

After the film had been shown and discussed, he told us the results of a research which had followed its showing

The use of a silvered hemisphere for reflecting a 360° view of the horizon in the lens of a photographic or cinematographic camera is nothing new, and pictures taken by the All Sky camera at the Royal Society's Halley Bay base in the Antarctic were published in DISCOVERY, 1957, vol. 18, pp. 210 and 211.



to groups of university students. In order to show the problem in its correct chronological order, I will describe the film as I saw it first.

A helicopter leaves the ground, and a student pilot is given a test flight. We go with him over the countryside, towns, rivers, and the sea. We hover over waterfalls and sink almost to ground-level, we begin to know the excitement and the flexibility of a modern helicopter. The film shows the strange beauty of this slow-moving yacht amongst the jet-powered supersonic aircraft of today. The film lingers on the world as seen from an almost stationary aircraft.

Next comes a clear and a reasonably slow sequence demonstrating the controls of a helicopter. It is elementary enough to give a first lesson in piloting. Briefly, the method of steering, of climbing, and descent is shown.

Next comes the highlight of the film. It is certainly one of the most fascinating sequences I have ever seen. Helicopters dance—yes, literally dance to music. Singly, in pairs, and in groups, they waltz and samba in exact time to music.

Colonel Greco told us that their timing was synchronised by playing the music from a ground radio-transmitter. The pilots heard the music through earphones and danced their planes according to a very carefully rehearsed choreography. They turned their tails, dipped, and curtsied in perfect rhythm and unison. The movements had the incredible precision of the musical drive at a searchlight tattoo.

From the point of view of film technique, the perfect touch was that they flew over a cornfield at the height of about 6 ft. As they turned and waggled their tails to a Latin American tempo, the grass was swirled into a following trail by their turning rotors.

This sequence gave poetry of motion, precision of timing, and a demonstration of the potentialities of the helicopter which used the film's power of plastic imagery to the full. Every scene was obviously the work of a craftsman film-maker disciplined by a skilled technician. Even the most fantastic ballet effects were sharply scientific and without trickery. It showed in a most entertaining way what a helicopter can do—and yet it has proved a complete failure!

Why?

The film was not intended as entertainment. Its object was to stimulate undergraduates to take up flying as a hobby, or to make the Air Force a career. The clear didactic sequence on how to fly a helicopter was intended to leave a lasting impression of simplicity, flexibility, and precision in the minds of the audiences. Quite brutally this did not prove to be the case. We are told that the Ministry of Aviation made a series of tests over a period of more than six months. Groups and individuals who had seen the film were asked at varying intervals after the screening what they remembered.

In relation to the intention, the results of the tests were entirely negative. Not one of the several hundred students questioned remembered anything about the helicopter controls. In fact quite a number of people categorically denied that the controls had been shown during the film.

Everyone remembered the film as excellent, some thought of it as a charming ballet on an unusual stage, others as a clever circus turn. The total result was a unanimous statement that it was first-class cinema, but in no case was there the slightest sign of a change of attitude towards flying. In some cases the reaction was: "Well, it must be very difficult to fly a helicopter, I don't think I could ever learn."

To me this is a most important finding. Here is an aviation film that is first-rate and technically compares favourably with the best of the Shell Film Unit's work. In some ways it is reminiscent of Basil Wright's "Song of Ceylon". Yet it is a mere distraction, because it puts the emphasis on the wrong things. The beauty and the poetry are right. It is only the order and the stress that leads the audience down blind alleys.

All too often good film directors become so fascinated with their subjects that they sacrifice scientific communication upon the altars of showmanship, technique, and virtuosity. The result is often good film-society material, but not a functional film which can be used to achieve a definite result. I am absolutely certain that anyone seeing "Samba 8 Ala Rotante" will thoroughly enjoy it, as I did. It is a prizewinning film, and no jury seeing it would, or even could, foresee its

Recently shown in Germany by Adalbert Baltes from Hamburg is the *Cinetarium*, which consists of a hemispherical mirror supported above the lens of a cine camera. It is here being demonstrated for a trick shot of the engine of the Trans-European Express travelling over it. There may be many more serious scientific uses of this principle in addition to the All Sky camera and a trick shot of a railway engine.

failure. Only objective tests and experience could bring to light the reasons why this film did not do the job it was intended to do. L. GOULD-MARKS

February Television

We have seen this month a meaningful, forceful difference between the output of science television on the two channels BBC and ITA. In fact, apart from normal schools broadcasts, ITA have offered us virtually nothing. On the contrary the BBC have excelled themselves, so much so that space limitation just prevents a fair account by your reviewer of the varied programmes. The BBC are to be congratulated indeed in at last recognising the part science plays in our modern culture. Consider just the one week February 22–8. There were no less than four schools science broadcasts, another two in Children's Hour, these being that old favourite "Look" by Peter Scott and an admirable programme on the technology of printing given by Arthur Garratt, and finally four adult science programmes. These were "Eye on Research", which is a regular series, Prof. A. C. B. Lovell in an adaptation of his Reith Lectures entitled "The Individual and the Universe", a programme on "Termination of Pregnancy", and finally another "Look" programme by Peter Scott.

This was indeed a noble effort which covered a large variety of subjects, yet ITA merely offered the adult light entertainment during this same period. The scientific news magazine of James McCloy, "Science is News", continues to bring to us a surprisingly varied range of subjects, all of which are invariably well illustrated. The February 5 edition had much to commend it. There had been a current newspaper scare about biological warfare and in particular botulin toxin. Showing an admirable news sense (and also, clearly, some pretty quick programme fixing) Mr McCloy brought to us Dr van Heyningen, an expert on botulism, and in an absorbing six-minute discussion with David Attenborough he soon scotched the newspaper talk. Dr Margerison followed with some film concerning visual signals and the occurrence of accidents due to human failure to recognise such signals. Mr Broadbent, a psychologist from Cambridge, was brought in and he showed some film relating to fatigue tests and expectancy errors with a number of subjects. He was rather obscure, however, when it came to interpretation. Closely linked was a discussion by Mr Burrows on possible errors arising in estimating readings of aircraft altimeters, and it is really interesting to note that new recommendations have recently been issued about this very matter. This whole section, which lasted twelve minutes, developed into an admirable three-way discussion. The broadcast ended with a review on blood pressure, initiated by "the Doctor". (Is it not time that viewers knew the name of one of the best of all television broadcasters). He used some excellent film and animation in a discussion on blood pressure and was joined in this by Prof. Paton, whose presentation, however, was probably above the heads of most laymen.

Two points struck your reviewer. One was that the whole broadcast was very much live current news, and as such was extremely well put together in what, by the nature of the material, must have been a very short time. Second, was the curious fact that all items treated were biological, indeed more so, referred to human biology or psychology. Most "Science is News" programmes have been more varied in their content, obviously on purpose. This exception certainly did not suffer from monotony, on the contrary it gained from unity.

The second "Science is News" programme for February was put out on February 19. This was again introduced by David Attenborough. There were three subjects in this broadcast. The first, which was illustrated by some very telling film, was effectively a discussion between Dr Newth and Dr Busvine on the battle being waged on a world-wide basis against insect infestation of humans, cattle, and plants. Insecticides, their successes and failures, were the main topic. This section was packed full of valuable material and held a surprisingly large content in the few minutes it was on the air.

This was followed by S. Tolansky who propounded one of his theories on why many snow crystals grow with a surprising degree of symmetry. The theory proposed was supported by experiments showing distribution of nodes on vibrating hexagonal plates, using close-up camera shots.

The programme finished with a novel discussion between "the Doctor" and Dr Tanner on Somatypes, a somewhat formidable name for what is effectively a classification of people into groups according to their physical build: bulkiness, lankiness and so on. This section was lightened by a number of amusing cartoons and illustrations. Mention was made of evidence which suggests that particular diseases are associated with particular physical types, a fact long conjectured of course. It was clear that some formidable analysis of statistics will be required in this field of investigation.

In considering these "Science is News" programmes as a whole, and not being concerned with any one programme, it is a matter of some surprise at first that so extraordinarily varied a range of subjects has been covered. The field seems endless; but surely this is a tribute to the versatility and news sense of the producer.

On February 24 "Eye on Research" gave us (with its usual strange sense of humour about titles) "The Particle Hunters". This was a half-hour visit, arranged both with film and live television from the Swiss Television Service, to the international research centre CERN, at Geneva. Here a large cyclotron and a giant synchrotron particle accelerator, which is expected to reach an energy of no less than 25,000 million volts is under construction. Raymond Baxter most ably interviewed a number of the young physicists at this establishment. Unfortunately, though, the broadcast was over-technical: the formidably difficult ideas behind the working principles of cyclotron and synchrotron surely require expounding by the very ablest of lecturers, and how well we know that the young men engaged in a research almost invariably over-elaborate their themes.

It is not enough to impress by the admittedly formidable character of the machine, which is impressive enough. We would have liked to have seen, if that were possible, a simple account of a complex matter; but that was not adequately achieved in this broadcast.

The novel broadcast of the month was a television adaptation of the recent Reith lectures on the "Individual and the Universe" which was put out by Prof. A. C. B. Lovell on February 25. This was produced by Paul Johnstone. It was a condensation of the six Reith lectures, with added illustrations and therefore a formidable undertaking in synthesis. The broadcast lasted forty-five minutes and was highly successful in every respect. Some delightful film was presented and in particular Prof. Lovell concentrated on an exposition of the two current conflicting cosmological theories, that of the primeval atom and that of continuous creation. The content was not easy going but every serious-minded viewer must have found it of absorbing interest. Perhaps one criticism can be levelled: that Prof. Lovell might have stressed a good deal harder the conjectural character of the material he was describing. Without meaning to (I am more than sure), he did at times leave the impression that what is really conjecture was actual fact.

A 12-foot model of our galaxy was set in rotation, in fact it was a large curved disc with fluffs of cotton-wool It looked most ordinary in the studio props room but was strikingly effective in the broadcast. The whole broadcast was brilliantly illustrated and repaid the obvious considerable care and thought which had gone into the presentation. S. TOLANSKY

FAR AND NEAR

Science in Parliament: January 20–February 20

With its reassembly after the Christmas recess, Parliament's proceedings bore witness to a wide spectrum of interest in scientific matters. Questions in the Commons, for instance, were asked about the Russian space-satellite contribution to the International Geophysical Year, the use of geophysical methods in the geological survey of Great Britain, progress in research on electrical heating of road surfaces, soil research for building sites, and the work of the National Physical Laboratory in connexion with the "atomic clock". The Government spokesman, incidentally, had some difficulty on February 3 in convincing his questioner of the value of the observations carried out through the operations of the last-named instrument.

Two of the most prominently featured items were safety in connexion with nuclear power stations, and fuel and power policy. The former was the subject of an Adjournment Debate (January 21), and also arose in the Second Reading Debate on the Nuclear Installations (Licensing and Insurance) Bill, which had been introduced and considered before Christmas in the House of Lords (DISCOVERY, 1959, vol. 20, p. 90). In the Adjournment Debate, information was sought as to the risks involved with nuclear power stations generally, and specifically, having regard to the incidence of strontium 90 in certain areas. Reassuring information came from the Parliamentary Secretary to the Ministry of Fuel and Power. As for the Nuclear Installations (Licensing and Insurance) Bill, this had an unopposed second reading (February 9) before its reference to committee. There was widespread acceptance of the need to licence reactors and to safeguard the position of the public and workers through compensation; the debate afforded a valuable interchange on safety problems and procedures. However, a matter causing special concern to Opposition speakers was the fear that there might, under the Bill, be difficulties in proving that a particular condition was due to a nuclear accident.

The contribution of science and research to an effective Fuel and Power policy (DISCOVERY leading article, "Tomorrow's Energy", 1958, vol. 19, No. 11, p. 445) was a recurring theme in the debates on this subject in the Lords (Wednesday, January 21) and in a Private Member's Motion in the Commons on February 6, both occasioned by the serious fall in the demand for home-produced coal. While speakers differed in their conception of the degree of competitiveness required from the varying sources of fuel, there was general agreement on the need to press ahead with research into the fullest utilisation of this indigenous product—a matter which the Ministry of Power had referred to his Scientific Advisory Council under Sir Alexander Fleck. While Government spokesmen had encouraging news of progress with "overground" gasification of poor-quality coal, concern, however, was felt by some members at the particularly inadequate level of expenditure on research into oil synthesis. Yet overshadowing the need for research into ever greater fuel efficiency were uncertainties as to long-range economic trends for different fuels, not least for nuclear energy. While the Government were, not surprisingly, afraid of "crystal-gazing", there were spokesmen of both parties who, reassuringly, urged a longer view.

The Lapps Are Becoming Residents

Lapps whose only home is still a camp and a tent will get new modern permanent dwellings in the near future. The local Council in Norway's biggest Lapp district in Kautokeino have worked out plans for a housing project for the 300 persons who still live in tents or ramshackle sheds all the year round. They belong to forty-five families who live from their reindeer herds, and have not sufficient income to finance the building of their own homes. The Council are now seeking ways to finance the project. The Lapps are fast becoming residents—many of the young people, after years in comfortable boarding schools, refuse to go back to tents and nomadic ways of living. Altogether there are about 22,000 Lapps in Norway.

crafts such as glass-blowing. Starting salary (men) from £320 (at 17½) to £530 (at 25 or over). Maximum (London) £690. Promotion prospects. Five-day week generally. Write Civil Service Commission, 17 North Audley Street, London, W.1, for application form, quoting S.59/59.

SENIOR SCIENTIFIC OFFICERS (*a*): SCIENTIFIC OFFICERS (*b*). Pensionable posts for men or women in all major scientific fields, including physics, chemistry, biology, meteorology, and mathematics. Age limits: (*a*) at least 26 and under 31, (*b*) at least 21 and under 28. Extension for regular Forces Service and overseas Civil Service. Qualifications: normally First- or Second-Class Honours degree in science, mathematics, or engineering, or equivalent attainment; additionally for (*a*), at least three years' relevant (e.g. post-graduate) experience. London salaries (men): (*a*) £1190–£1410, (*b*) £635–£1110; provision for starting pay above minimum. Promotion prospects. Write Civil Service Commission, 17 North Audley Street, London, W.1, for application form, quoting (*a*) S.53/59, (*b*) S.52/59.

PATENT EXAMINERS AND PATENT OFFICERS. Pensionable posts for men or women for scientific, technical, and legal work on Patent applications. Age at least 21 and under 28, with extension for regular Forces Service and overseas Civil Service. Qualifications normally First- or Second-Class Honours degree in physics, chemistry, engineering, or mathematics, or equivalent attainment, or professional qualification, e.g. A.M.I.C.E., A.M.I.Mech.E., A.M.I.E.E., A.R.I.C. London salary (men) £635–£1410; provision for starting pay above minimum. Promotion prospects. Write Civil Service Commission, 17 North Audley Street, London, W.1, for application form, quoting S.128/59.

R.A.E. RESEARCH FELLOWSHIPS

MINISTRY OF SUPPLY invites application for a limited number of SENIOR and JUNIOR RESEARCH FELLOWSHIPS tenable for two or three years at the ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH, Hants, commencing Autumn 1959.

FELLOWS will be required to carry out Fundamental Research in connexion with advanced rocket and aircraft projects. The scientific fields covered include aerodynamics, thermodynamics, aircraft and missile structures, guidance and control techniques, etc. Subjects will be selected according to the training and experience of the Fellows and the interests of the Establishment.

Candidates must be British with normally a First- or Second-Class Honours degree in the Natural Sciences, Mathematics, or Engineering, with evidence of a very high standard of ability in research. Exceptionally, a candidate without the academic requirements but who can produce evidence of outstanding ability in research, may be admitted. At least two years' post-graduate research experience required for J.R.F. (age preferably 23–26) and three years for S.R.F. (age preferably 26–30).

REMUNERATION according to individual merit on ranges £1100–£1350 (S.R.F.), £750–£1000 (J.R.F.) a year. Superannuation under F.S.S.U. At the expiry of Fellowship the holder, if of suitable age, can be considered for an established post at the Establishment.

APPLICATION FORMS from the Director, R.A.E., Farnborough, to whom completed forms, together with suitable testimonials regarding research ability and, where possible, copies of candidates' published papers, must be returned by April 17, 1959. Overseas candidates should submit written applications stating age, nationality and place of birth of self and parents, academic qualifications, appointments held and research experience.

UNIVERSITY OF BIRMINGHAM WILMOT BREEDEN RESEARCH FELLOWSHIP, 1959

APPLICATIONS are invited for a Research Fellowship to be held in association with the University of Birmingham. The value of the Fellowship, which is for a two-year term, is £1000 p.a.

A candidate for the Fellowship should normally have had two or three years' research or industrial experience. He must be acceptable to the University and would be expected to have an Honours Degree of a University in the British Commonwealth, a Diploma in Technology or an equivalent qualification.

The Wilmot Breeden Fellow will engage in an enterprise of such a character as to require the facilities both of the University and the Company, and his time will be divided between the two. The activities with which the Company is especially concerned include Mechanisms, Electro-Chemistry, Metal Finishing, Metallurgy, Metal Formation, Hydraulics, Electronics.

Full details may be obtained on application to the Secretary, Wilmot Breeden Limited, Amington Road, Birmingham, 25. Final applications must be received by the Secretary before May 1, 1959.

GRANTS & SCHOLARSHIPS

NATO STUDENTSHIPS AND FELLOWSHIPS IN SCIENCE AND TECHNOLOGY

THESE AWARDS for post-graduate and post-doctoral study in science and technology (including medical and agricultural sciences, industrial psychology and sociology) are available to British subjects normally resident in the United Kingdom and can be held in NATO or non-NATO countries.

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Further information can be obtained from heads of departments of science and technology at universities and colleges, through whom all applications should be sent to DSIR, Charles House, 5–11 Regent Street, London, S.W.1, as soon as possible.

LECTURES AND COURSES

UNIVERSITY OF OXFORD DELEGACY FOR EXTRA-MURAL STUDIES SUMMER SCHOOL IN SCIENCE

July 28–August 11, 1959

to be held in Queen's College, Oxford, and University Science Departments. Laboratory and field courses of study for one or two weeks in Natural History, Vertebrate Animals, Chemistry, Biochemistry and Physics, and special week-end courses in Genetics and Plant Parasites; with a lecture course on Evolution. The courses are given by lecturers and demonstrators from the Departments of Zoology, Agriculture, Organic Chemistry, Biochemistry and the Clarendon Laboratory, and attention is paid to students' preferences in individual work. The programme should be of special interest to teachers of Science, scientists and technicians engaged in industry, members of adult classes and others who wish to extend their knowledge and understanding of science. Fee £10 per week inclusive (reduced rate for students from adult classes £7 7*s.*); week-end courses: Plant Parasites £3 5*s.*, Genetics £4 17*s.* 6*d.*

Full particulars may be obtained from the Secretary, Science Summer School, Oxford University Delegacy for Extra-Mural Studies, Rewley House, Wellington Square, Oxford. Telephone: Oxford 57203.

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